DEAR Technical Note IR-29

Report on the run period August-September 2000: NTP setup with CCD detectors

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1) Introduction

The first step of the DEAR scientific program is performed with a NTP target (Normal Temperature and Pressure) filled with nitrogen. The NTP setup, described in Refs. [1,2], was installed on the DAΦNE machine in February 1999. Since that time many measurements have been performed with beams separated in the DEAR interaction point (IP) [1,3-9]. Beams colliding in the DEAR IP could only be investigated for one short period in December 1999 [2]. In this first collision period the background was observed to be too high and the accumulated luminosity too low to allow a kaonic nitrogen signal to be seen.

During the winter shutdown two major tasks have been accomplished on the accelerator: the installation of new HOM damped injection kickers and the realignement of the KLOE low-beta triplets (which were found misplaced by ~ 1 mm). Concerning the setup of the DEAR experiment, a re-inforced set of lead walls at the two sides of the DEAR interaction region was installed. The walls are 10 cm higher than those installed in December 1999 and have an additional layer, 20 cm high and 5 cm thick, all around the beam pipe.

A second period of runs with beams colliding in the DEAR IP was assigned from August 24 until September 11, 2000. The beam period was devoted to two main goals, namely understanding and reducing the background in the DEAR region and increasing the luminosity. A visible pattern of lines of kaonic nitrogen x-ray transitions is indeed expected by collecting only some pb^{-1}, if a "reasonable" signal-to-background ratio is reached.

A third task was pursued: to try, for the first time, to obtain collisions in both interaction points of DAΦNE, namely the DEAR IP and the KLOE IP.

2) The measurements with the CCD detectors in the August-September 2000 runs

The effective period of data taking with collisions in the DEAR IP started on August 31, and lasted until September 11, 2000. The first 2 days were used to run in double crossing mode for the first time in DAΦNE. All the efforts were then concentrated towards background reduction, starting from and comparing with the measured level in the first period of collisions in the DEAR IP, in December 1999. The last 60 hours were finally dedicated to a stable period of data taking, with all machine parameters blocked at the values which had given the more significant reduction of the background. The total integrated luminosity collected in this last period amounted to 172.1 nb^{-1}, as estimated by the DAΦNE luminosity monitor.

3) Measurements with two simultaneous crossing points in DAΦNE

The importance – in scientific, strategical, "political" terms – of having a collider originally designed for two interaction points – for which, by the way, three experiments had been approved and financed – fully exploiting its planned performance, namely just making its "duty" by colliding the beams simultaneously in both interaction regions, is obvious and evident.

This "ambitious" task was tried at the beginning of the DEAR runs, apparently after some positive results obtained in a series of simulations performed by the machine staff. A double-crossing in the DEAR and KLOE IPs was indeed obtained, reaching peak luminosities up to 0.7×10^{30} cm^{-2} s^{-1} and 1.1×10^{30} cm^{-2} s^{-1} in DEAR and KLOE, respectively.

A preliminary estimation of the background measured in the DEAR setup turned out to be about 880 ± 80 Clusters/CCD/Beamloss [mA], from now on called D.u. (DEAR units) – a definition of the quantities which are adopted by DEAR for the background measurements can be found in Refs. [1] and [2]. This background is 5 times higher than the one measured in December 1999, in the machine configuration, and in the working point, existing before the shutdown.

The work of optimizing the beam features in both interaction points, eventually increasing luminosity, reducing background and getting stable running conditions, turned out, in practice, to be too hard, if not useless, given the present status of commissioning and knowledge of the machine. After two days of efforts, it was therefore decided to stop, for the moment, this test of double-crossing.

4) Study of background reduction: measurements of the number of clusters

After the exploratory effort of the simultaneous double-crossing in DAΦNE, the machine turned back to the "standard collision mode" with one interaction point, namely with the electron and positron beams colliding in the DEAR IP and splitted vertically in the KLOE IP.

Beam period	**Background (D.u.)**
December 1999 [2]	155 ± 8
September 2000 (two crossing points)	880 ± 80
September 2000 (collisions in DEAR IP) initial background level	1340 ± 100

Tab.1: Comparison between the background levels in DEAR in December 1999 and September 2000, at the beginning of the runs.

The start of the data taking was characterized by a background situation which was a factor of about 9 worse with respect to the pre-shutdown situation, as well as also worse (a factor of 1.5) with respect to the recent background measurements in the double-crossing configuration. The situation at the beginning of the runs is summarized in Table 1.

A series of efforts in order to improve the situation was then tempted. A relevant fraction of the runs – typically half a day – was dedicated by the DAΦNE staff to improve the machine performance, by tuning the significant parameters. In parallel, DEAR investigated the dependence of the measured background on the tuning of the beams (orbit corrections, optics adjustement, etc.).

Moreover, DEAR explored the effect on background reduction obtained by:

- using the horizontal scrapers on electrons and on positrons in the DEAR region;
- using the vertical scrapers on electrons and on positrons in the DEAR region;
- using the horizontal scrapers on electrons and on positrons in the KLOE region, (assuming that the splitting might represent a background source);
- the change of the crossing angle in the DEAR IP;
- the change of the vertical direction of trajectories in the DEAR region.

In the following Sections, typical effects on background produced by the above tools are reported.

4.1) The effect of scrapers on the background measured in DEAR

A sketch of the scrapers which are available for the two interaction regions of DAΦNE is given in Figure 1. All the scrapers can be moved individually. It is important to have independent movements on both sides of the beam axis because the closed orbit is displaced from the center of the vacuum chamber when the crossing angle is changed and, due to the sextupoles, the trajectories are not symmetric [10].

All scrapers were initially positioned out of the beam pipe. They were moved stepwise inside the beam pipe where they should cut only the particles following orbits different from the central one, typically produced by Touschek scattering. The movements were such as not to affect dramatically the beam lifetime.

The insertion of the scrapers in the DEAR region – both horizontal and vertical – had observable effects only at the percent level. The scrapers at the KLOE side turned out to be more effective, as they cut the background by about 70 %. This might be interpreted as an evidence of the fact that the splitting of the beams in the KLOE region creates a source of background. The scarce effect of the scrapers in the DEAR region might as well come from a sort of compensation between the effective cut of the "beam halo" and the new background created by the scrapers themselves.

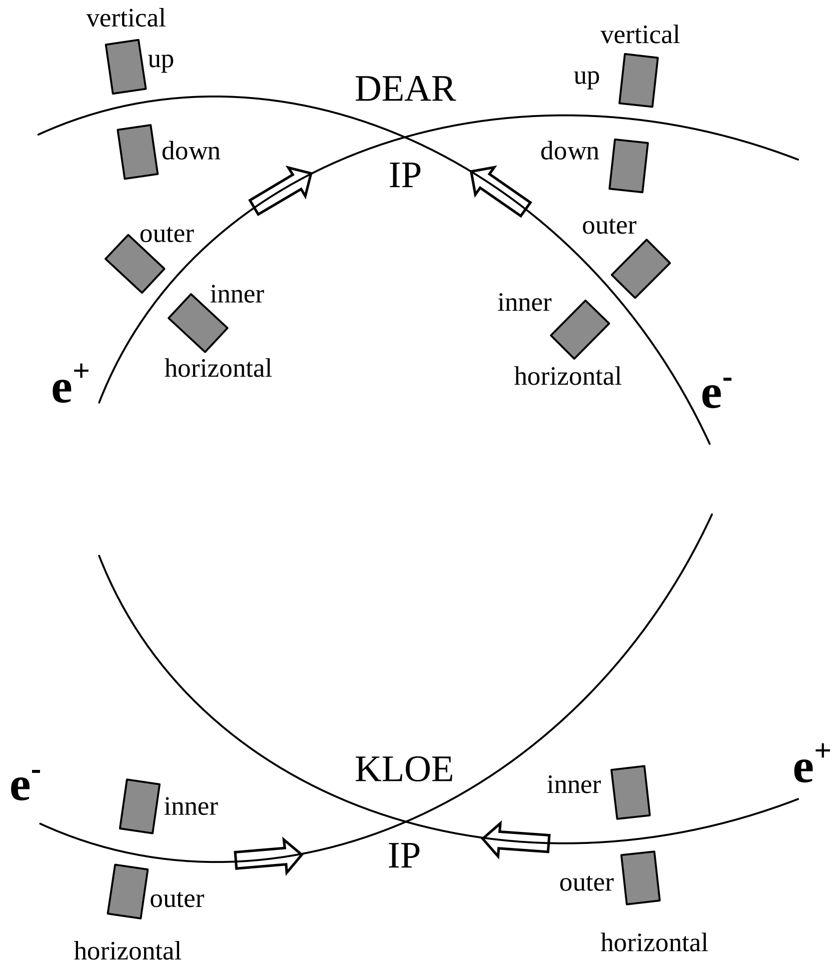

Fig.1: A sketch of the scrapers' locations in the DAΦNE rings.

In Figure 2 the effect of the insertion of the scrapers on the KLOE side with respect to the measured background in DEAR is shown.

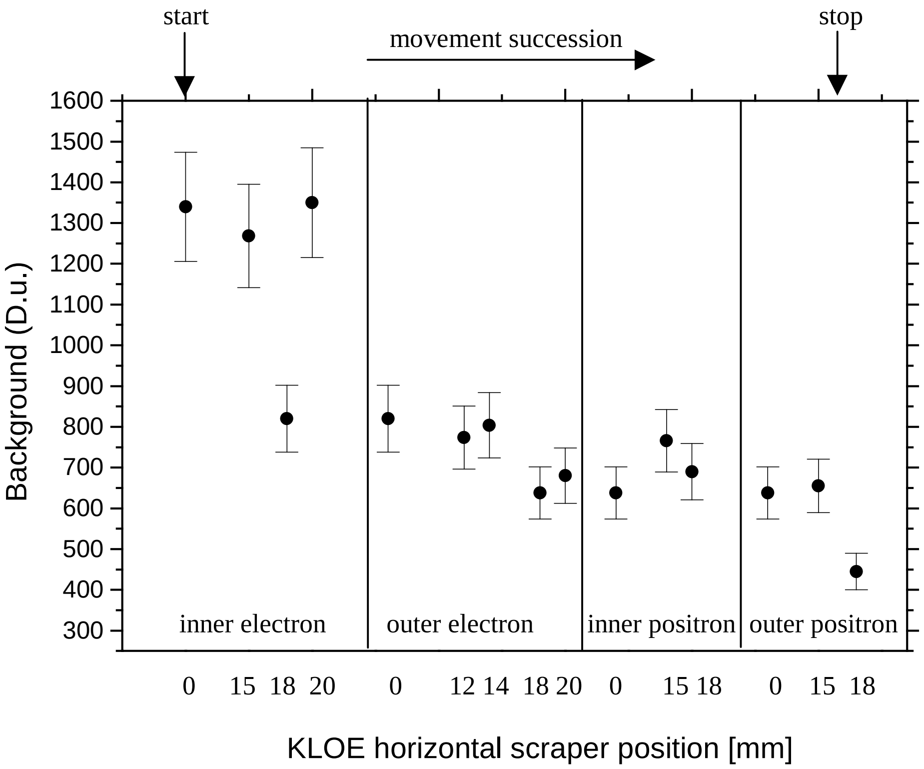

Fig.2: Dependence of the background in DEAR on the position of the scrapers on the KLOE side. First the inner electron scraper was inserted, followed by the outer one, then the inner positron scraper, followed again by the outer one. The successive improvement of the background is evident.

4.2) The effect of changing the crossing angle of the beams on the background measured in DEAR

As recalled in the previous Section, a change in the crossing angle in the radial plane displaces the closed orbit from the axis of the pipe and, consequently, has direct consequences on the beamlosses due to Touschek effect [10,11]. In the same time, changing the crossing angle affects the machine luminosity. Therefore the operation to try to reduce the background by changing the crossing angle has to be performed with specific care.

The dependence of the measured background on the horizontal crossing angle was explored by changing successively, in steps of 0.5 mrad, the electron crossing angle with respect to the set reference half crossing angle θ = 12.5 mrad, both in the horizontal and in the vertical planes. Figure 3 shows the dependence of the measured background on the variation of the horizontal crossing angle. With respect to the reference setting, only about a 10 % improvement was gained.

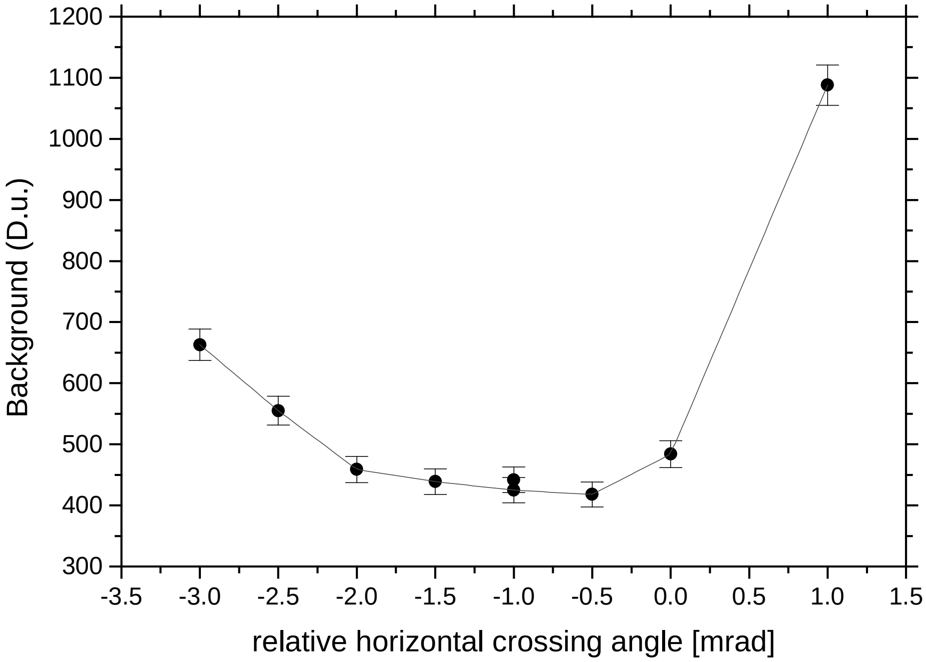

Fig.3: The dependence of the background in DEAR on the relative horizontal crossing angle of the beams in the DEAR IP. For the scan, the electron crossing angle was changed. The angle is given in mrad with respect to the DAΦNE reference setting (here indicated with 0).

As far as the vertical crossing angle is concerned, the reference setting turned out to be already the one which minimizes the background, as shown in Figure 4. A change of ± 0.5 mrad with respect to the reference already increased the background.

The scanning was finally repeated by tuning the positron crossing angle both for the horizontal and for the vertical planes. Identical results were eventually obtained.

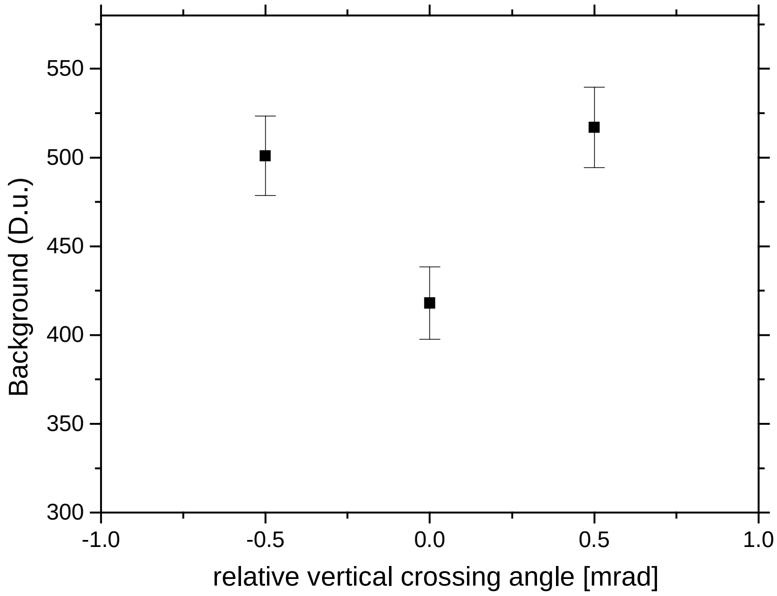

Fig.4: The dependence of the background in DEAR on the relative vertical crossing angle of the beams in the DEAR IP. For the scan the electron crossing angle was changed. The angle is given in mrad with respect to the DAΦNE reference setting (here indicated with 0).

4.3) Summary of the results to reduce the background

Scrapers: The expected large effect in background reduction by inserting the scrapers, an effect of orders of magnitude, as reported in Refs. [10] and [11], was not observed. The overall background reduction effect obtained by the insertion of scrapers was about a factor of 3.

Crossing angle: Again, an eventual strong dependence of the background on the horizontal crossing angle was not found, a 10 % reduction could at most be obtained.

The global reduction reached after an extended use of all the "simplest" tools at disposal to fight the background is reported in Table 2, which completes Table 1. The previous conditions, both pre-shutdown and after it, in the “double-crossing mode”, are as well reported.

Beam period	**Background (D.u.)**
December 1999 [2]	155 ± 8
September 2000 (two crossing points)	880 ± 80
September 2000 (collisions in DEAR IP) before background reduction	1340 ± 100
September 2000 (collisions in DEAR IP) after background reduction	400 ± 40

Tab.2: Actual status – in DEAR units – of the background level in the experimental setup at the end of the runs of September 2000. For comparison, the previous levels are also reported.

The overall reduction of the background obtained in the runs amounted to a factor of about 3.3 . This means that with respect to the state of the machine before the shutdown, with the previous working point, the background level is worsened by about a factor 2.6 .

Two observations are worthy to be done. The insertion of the scrapers, as well as the change of the crossing angle, were performed after only a preliminary tuning of the beam parameters. Due to lack of time, no iterative procedure could however be applied, namely, for instance, a retuning after the scrapers insertion and, then, a new positioning of the scrapers, as well as changes in the crossing angle.

The second observation concerns the nature of the background. As stressed above, only small factors could be gained in the efforts to reduce background with “conventional” tools. This legitimates the suspect that Touschek effect cannot be the only cause in producing losses from the circulating beams. Other reasons play probably in this case a major role: an anomalous coupling, a grazing of the pipe, other reasons. One has to admit that particles are lost for mostly unknown reasons in unknown regions of the rings. Not precisely an encouraging input for the battle against background.

5) Measurements of X rays

5.1) The ratio X rays to clusters

In Refs. [1] and [2] it was found that the ratio number of X rays per keV divided by the number of clusters was constant for all observed beams and beam conditions: single electron and positron beams, beams colliding in KLOE and splitted in DEAR, beams colliding in DEAR and splitted in KLOE. The corresponding value of the constant is specific to a given setup. This constancy allows one to use the number of clusters as a measure of the background rate, being a number much faster to be measured than the number of X rays. The constancy of the ratio X rays / Clusters was therefore again checked during this run period. In Figure 5 this ratio is shown over a full collision period on September 8, 2000. The X rays per keV are counted in the "region of interest (ROI)" equal to 6.15 ± 0.6 keV (BGX_{ROI}) [1]. The errors are large due to the low number of X rays observed in a single 1.5 minutes measurement, but the constancy is clearly seen. The mean value for the observed period, BGX_{ROI}/Clusters = $(9.5 \pm 3.4) \times 10^{-4}$, agrees well with the values given in [1,2].

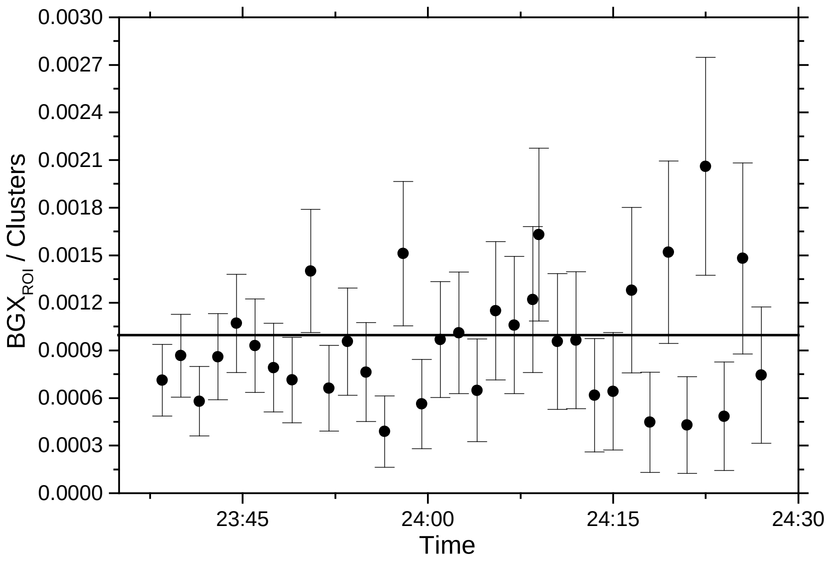

Fig.5: Number of X rays per keV in the region of interest divided by the number of clusters for a collision period on September 8, 2000. The line gives the calculated mean value.

5.2) X-ray energy spectrum from this data taking period

The final goal of the DEAR NTP measurement is the observation of kaonic nitrogen x-ray transitions. In the last days of this run period 172.1 nb^{-1} of integrated luminosity, as estimated by the DAΦNE luminosity monitor, was collected under stable machine conditions, with all parameters at the values which had given the relative lowest background. This allowed to accumulate an x-ray energy spectrum which is shown in figure 6. The positions of the two most easily observable kaonic nitrogen transitions at 4.58 keV and 7.58 keV are indicated. The expected count rate for the collected integrated luminosity is around 11 counts for both peaks, which is by far too low to be significant at the present background level. ("magra saddisfazione!") The fluorescence peaks of the target material (aluminum), of the silicon of the CCD chip and of the introduced zirconium foil at the kaon entrance window are clearly visible. The shape of the Bremsstrahlungs background seems to be a bit steeper with respect to the corresponding spectrum observed in December 1999.

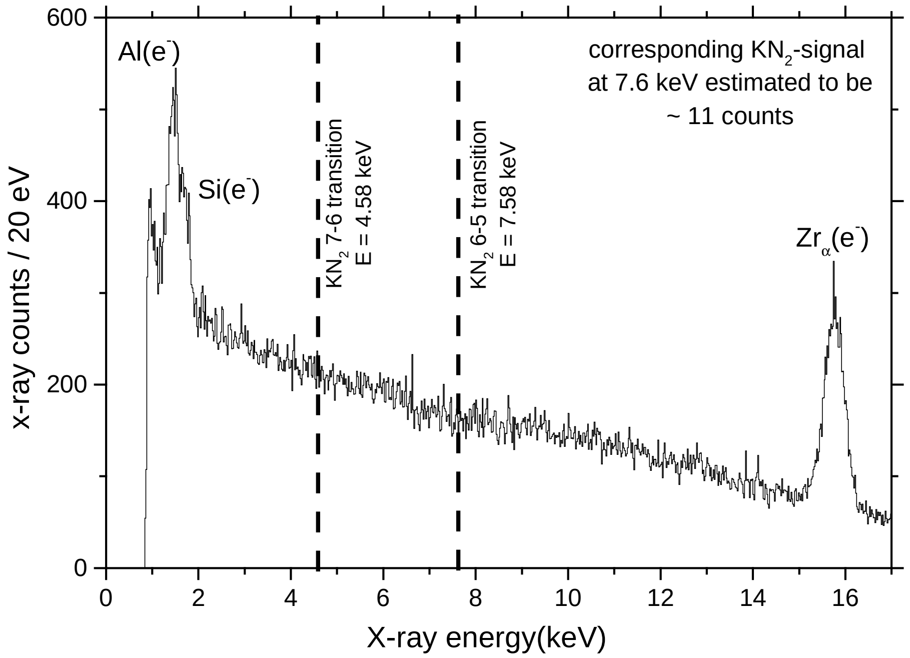

Fig.6: Energy spectrum of X rays observed in the period of beams colliding in the DEAR interaction region (corresponding to about 172.1 nb^{-1}). The calculated positions of two kaonic nitrogen transitions are indicated. Electronic x-ray lines from aluminum, silicon and zirconium are clearly visible.

6) Luminosity in the DEAR interaction point

All the given luminosity values are estimations produced by the DAΦNE luminosity monitor. These values do not substantially disagree with the measurements performed by the DEAR kaon monitor [12] during its development work in this run period.

6.1) Peak luminosity

The luminosity value at the beginning of each period of collisions (between two injections) was considered. By taking into consideration the last 60 hours of stable data taking, the average peak luminosity in DEAR turned out to be:

$$< \mathcal{L} > = 2.5 \times 10^{30}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ . \qquad (1)$$

A maximum value $\mathcal{L}_{max} = 5 \times 10^{30}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ was registered.

In Table 3 the comparison between the actual peak luminosity and that one measured in December is done. From the Table, it turns out that the average peak luminosity is increased by about a factor 4.2 with respect to December 1999.

Beam period	**Peak luminosity $\mathcal{L}$**
December 1999	$0.6 \times 10^{30}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$
September 2000	$2.5 \times 10^{30}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$

Tab.3: Machine luminosity in December 1999 and in September 2000.

6.2) Integrated luminosity

In the stable period of data taking an integrated luminosity of

$$\mathcal{L}^{int}_{collected} = 172.1 \text{ nb}^{-1} \tag{2}$$

was collected in 60 hours.

This corresponds to an average integrated luminosity per day

$$< \mathcal{L}^{int}_{d} > \cong 70 \text{ nb}^{-1} / \text{d} \tag{3}$$

or to an average integrated luminosity per hour

$$< \mathcal{L}^{int}_{h} > \cong 3 \text{ nb}^{-1} / \text{h} \ . \tag{4}$$

In the last night, however, one could get the maximum value for the integrated luminosity per hour $(\mathcal{L}^{int}_{h})_{max} \cong 5 \text{ nb}^{-1} / \text{h}$ whose extrapolation to a full day gives $(\mathcal{L}^{int}_{d})_{max} \cong 120 \text{ nb}^{-1} / \text{d}$.

These values cannot be compared with analogous ones collected in December 1999, since that run period eventually consisted in a series of short runs, few hours or less long each, making meaningless to give a number for the integrated luminosity as performance of the machine over a sufficently long (at least 24 hours) period.

6.3) Machine efficiency

The average peak luminosity in the period of stable data taking reported above ($< \mathcal{L} > = 2.5 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$) would give, over the duration of the period (T=60 hours) an expected integrated luminosity

$$\mathcal{L}^{int}_{expected} = < \mathcal{L} > \times \text{T} = 540 \text{ nb}^{-1} \ . \tag{5}$$

Knowing the effective collected integrated luminosity $\mathcal{L}^{int}_{collected}$ given by (2), an estimation of the actual machine efficiency ε_M can be deduced:

$$\varepsilon_M = \frac{\mathcal{L}^{\text{int}}_{\text{collected}}}{\mathcal{L}^{\text{int}}_{\text{expected}}} \cong 32\ \% \quad . \tag{6}$$

The inefficiency was found to be due to an articulated series of technical reasons, among which it could be checked that a substantial role was played by difficulties in injection.

7) Conclusions

This period of measurements with collisions in the DEAR IP from August 31 to September 11, 2000 has yielded the following results:

- for the **first time double collisions** (simultaneously in the DEAR IP and the KLOE IP) were achieved;
- the **background observed** with beams colliding in the DEAR IP (splitted in KLOE) **turned out about 2.6 times higher** with respect to the one observed in the collision period of December 1999;
- the **average peak luminosity was increased by a factor of 4.2** with respect to December 1999, reaching a maximum of 5×10^{30} cm^{-2} s^{-1} and an average value of 2.5×10^{30} cm^{-2} s^{-1};
- **the overall improvement of the accelerator performance (signal/background) was therefore about 1.6;**
- the average integrated luminosity per day was about 70 nb^{-1}/d in stable beam conditions;
- the DEAR NTP setup equipped with the CCD x-ray detectors worked very well, however the present background level is far too high for the present luminosity to allow the unambiguous detection of a kaonic nitrogen signal.

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