DEAR Technical Note IR-30

Report on the run period August-September 2000: Kaon Monitor

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1 Introduction

The DEAR kaon monitor not only will allow the determination of the absolute yields of the X rays transitions which give the pattern of lines of the kaonic atoms spectra, but can also be used to obtain a precise determination of the machine luminosity. It can also accurately tune the machine energy on the ϕ-resonance. A kaon monitor must satisfy the following requirements:

- fast response;
- identification of charged kaons from background;
- reasonable counting rate, also at a luminosity of the order of $10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$.

In December 1999, during the first DEAR data taking on DAΦNE, that lasted only few days, kaons were identified using a time analysis which allowed to separate the slow charged kaons from the fast background particles. The amplitude analysis of signals was not, however, implemented at that time, and hence the cross check allowing an unambiguous kaon identification (longer times *and* high amplitude pulses generated from scintillators due to the slow, highly ionizing charged kaons) could not be performed.

In the second DEAR run period, from 31 August to 11 September 2000, not only time analysis but also amplitude analysis of the pulses from the scintillators were simultaneously performed, and kaons were successfully identified in the TDC versus ADC spectra. Having obtained a clean kaon identification, the determination of the integrated luminosity delivered by DAΦNE in the measurement interval could be done.

The present Note presents the experimental results in terms of data taking and analysis.

Section 2 recalls the experimental features of the kaon monitor, while in the third Section experimental data are presented as TDC versus ADC spectra. Section 4 deals with data analysis and specifically with the procedure of subtracting the background - fast, minimum ionizing particles (m.i.p.s), mainly positrons and electrons - and extracting the kaon signal. In Section 5, how to use the kaon monitor as luminosity monitor is described. Section 6 contains conclusions and perspectives, based on the results obtained in this period of data taking.

2 The kaon monitor setup

As described in [1], and shown in Fig. 1, the kaon monitor is made by two thin scintillators, which are fast NE104, 2 mm thick each. The scintillators are both 8 cm high and 15 cm long and are placed back-to-back, in front of the interaction point (IP), at the two sides of the DEAR pipe, parallel to it and perpendicular to the horizontal plane. Each scintillator is seen by two fast XP2020 phototubes. During the August-September 2000 data taking the scintillators were at about 14 cm from the IP (about 9 cm from the beam pipe).

The analogical signals from each phototube are sent to a Dual Constant Fraction and Mean Timer Module, in order to obtain a timing independent both on pulse height and on the crossing point on the scintillator. The module releases also (attenuated and delayed) analogical input signals which can be used for any subsequent linear analysis. In Figure 2, the scheme of the electronics used in the measurements is shown.

The time-of-flight distribution of the coincidences between the two scintillators and the amplitude signal of the inner scintillator were simultaneously recorded. Differently from the previous measurements in December 99, the

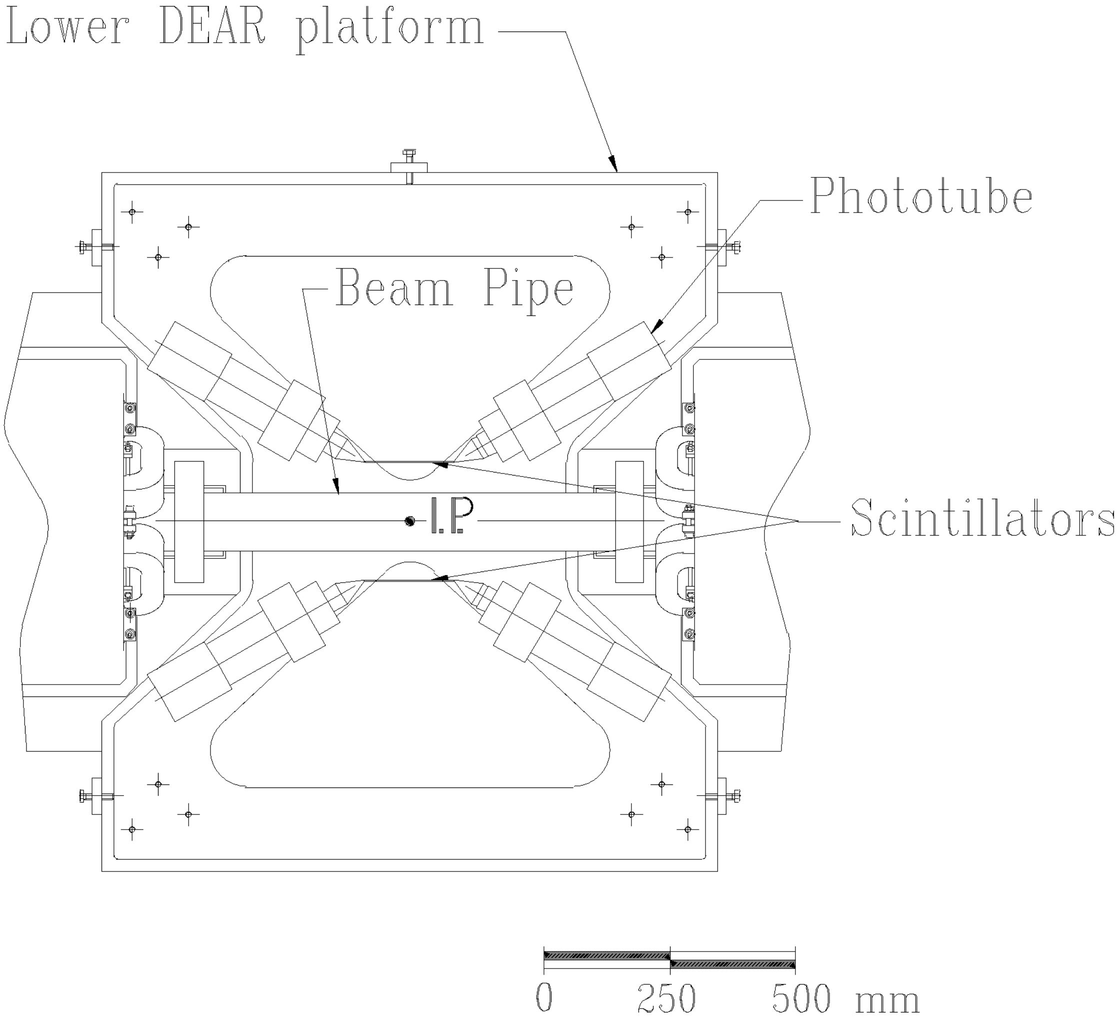

Figure 1: The Kaon monitor setup

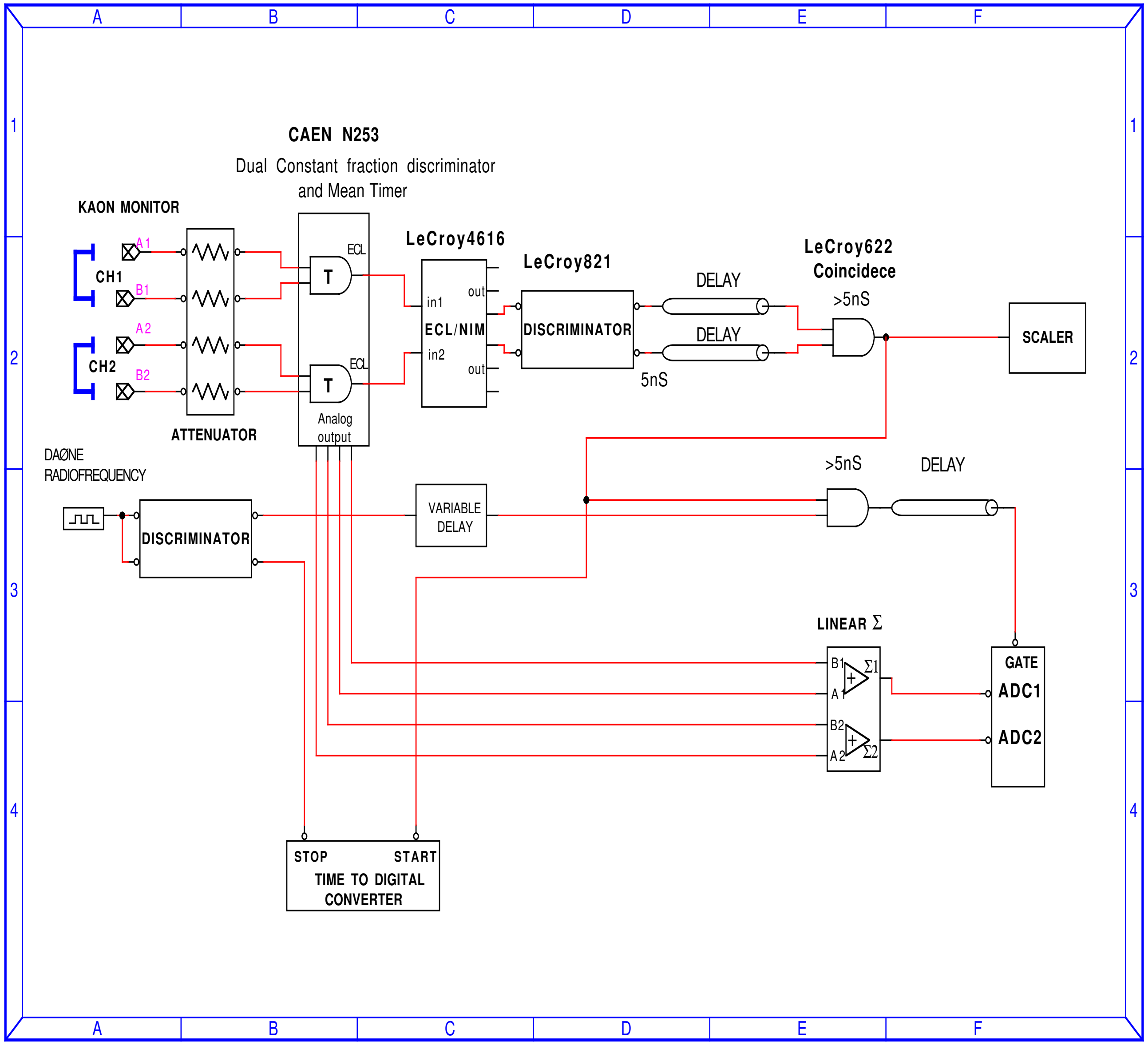

Figure 2: Scheme of the Kaon monitor electronics.

machine RF signal, divided by 6, was used, instead of the bunch signal. This signal provides the clock for the time measurements and gives the STOP to the time analysis circuit, while the START is given by the coincidence. The circuit has a *50 ps* resolution per channel.

3 Experimental results

The first period of data taking was dedicated to the optimization of the system performance. Then, a series of 10 runs of comparable integrated luminosity, in stable machine conditions, were collected, for a total acquisition time of 4 hours and 45 minutes.

The TDC spectra as well as the ADC ones were simultaneously registered.

A bidimensional TDC versus ADC spectrum corresponding to the sums of the 10 runs is given in Fig. 3. The slow, high pulse events which characterize kaons from background can be clearly identified. The twin structures which appear in the figure are simply due to the chosen frequency for the STOP (RF/6), together with the "module three" configuration for filling the bunches (20 bunches, one filled every three).

The time-of-flight spectrum given by TDC, corresponding to the sum of the 10 runs, is shown in Figure 4. Two twin double peaks are evident, for the above reasons, each constituted by a huge background peak given by the m.i.p.s, accompanied by a smaller peak due to kaons. The time-distance between background and signal peaks turned out about 1.8-1.9 ns, in good agreement with the Monte Carlo results.

4 Data analysis

After having recorded, for each event which gave a coincidence between the two scintillators of the setup, the TDC versus ADC information, the data were processed according to a TDC/ADC coupled analysis. The procedure followed to extract from the recorded spectra the effective number of the K^+K^- pairs which reached the scintillators, after background subtraction, is reported below.

In order to emphasize the kaon signal in the ADC spectrum, the kaon peaks in the time-of-flight spectrum were isolated by cuts (indicated as A

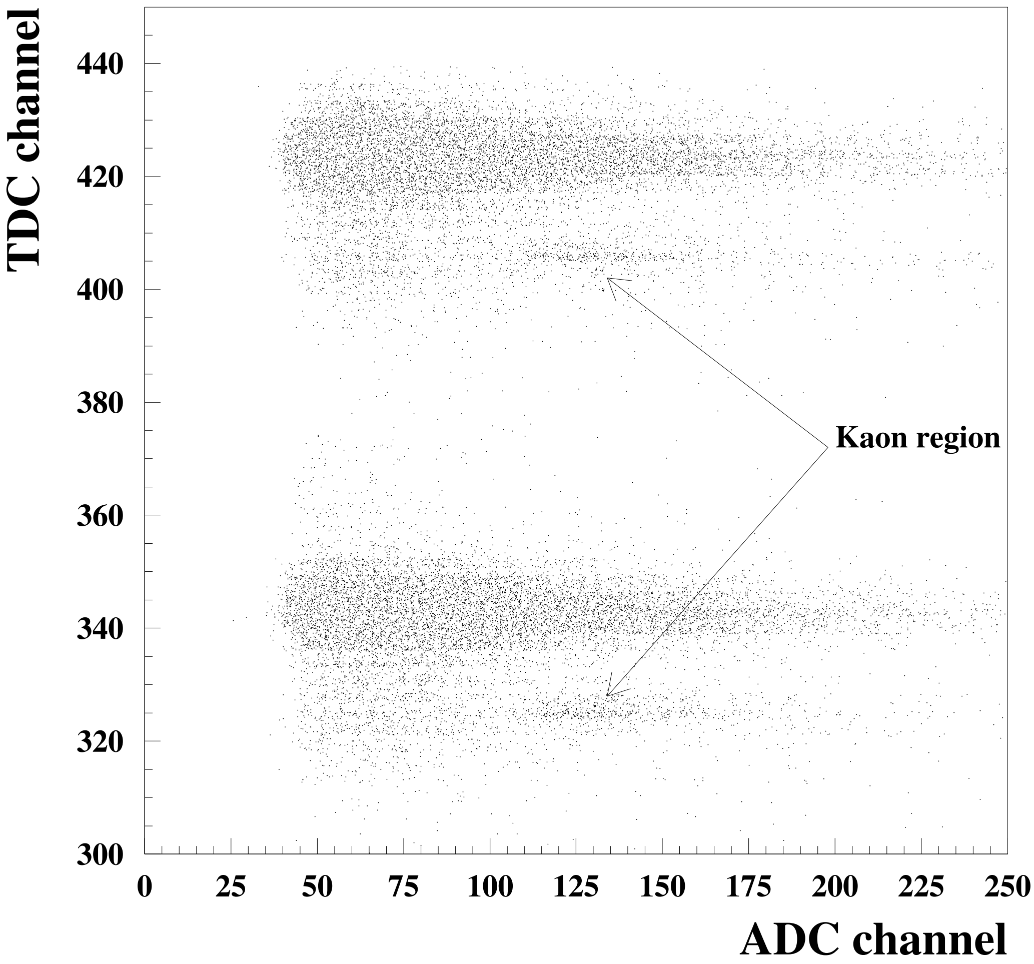

Figure 3: The bidimensional TDC versus ADC spectrum for the sum of 10 runs obtained with the kaon monitor.

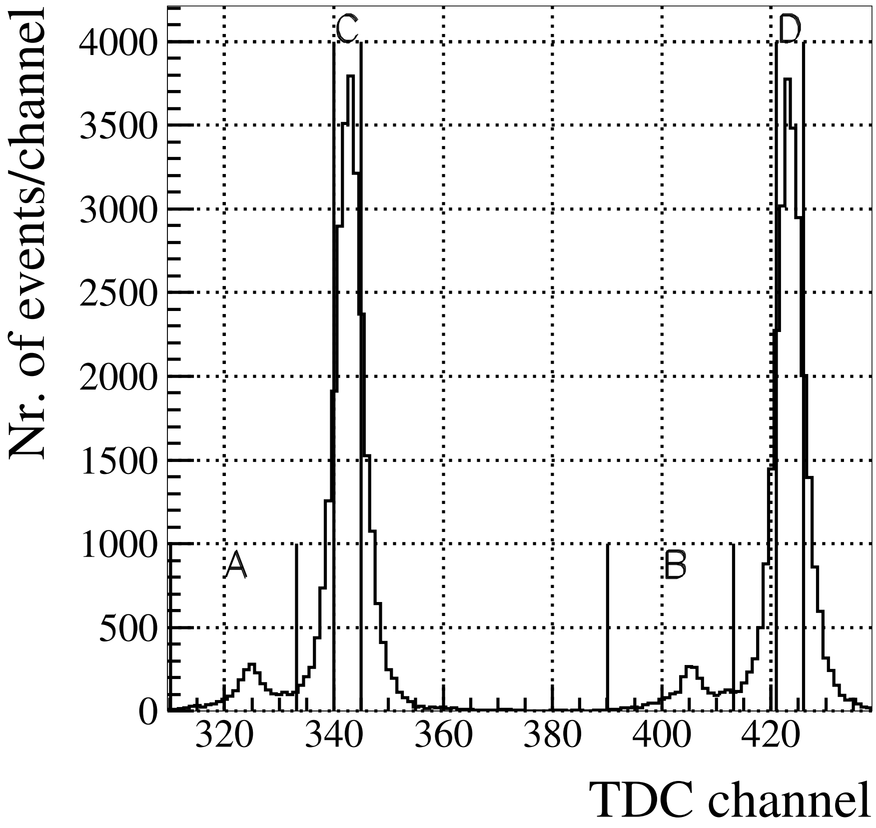

Figure 4: The time-of-flight TDC spectrum for the sum of 10 runs obtained with the kaon monitor. Regions A and B are indicating the kaon peaks, while C and D indicate the regions of the m.i.p.s.

and B in Fig. 4). The corresponding ADC spectrum is given in Figure 5. The highly ionizing slow kaons peak is clearly visible, together with the tail of the background (the apparent peak-shape of background is simply due to a threshold effect).

In order to perform a fit and extract the kaons number, it was necessary to have the background shape. This could be obtained by selecting a central region in the m.i.p.s peaks, where no kaons should be present (indicated as C and D in the time-of-flight spectrum of Fig. 4). The resulting ADC background spectrum is shown in Figure 6. As expected, no peak due to heavily ionizing particles is present.

Having the shape of the background, a fit of the ADC spectrum of Fig. 5, whose regions were selected with cuts on the time-of-flight spectrum (Fig. 4), was performed. The results of the fit are shown in Figure 7.

The total number of kaon pairs resulting from the fits, after the subtraction of background, is:

$$N(K^+K^-)_{fitted} = 1850 \pm 180, \tag{1}$$

where the error is given by the *error on the fitting parameters*.

From this number, knowing the Monte Carlo calculated acceptance of the monitor, one can obtain the overall number of K^+K^- pairs from ϕ decay created in an e^+e^- collision. The latter is the relevant quantity to be considered in evaluating the kaon flux through the entrance window of the DEAR setup and, hence, in deducing the yields of the kaonic atoms transitions, after measuring the intensities of the pattern of lines of the spectra using the CCD detectors.

5 Measurement of the luminosity in the DEAR IP by using the kaon monitor

The luminosity value in the DEAR IP can be directly obtained by the kaon rate measured by the kaon monitor. One has, in fact:

$$R(K^+K^-) = \mathcal{L} \times \epsilon_{KM} \times \epsilon_D \times \sigma(K^+K^-) \tag{2}$$

where $R(K^+K^-)$ is the rate (kaons/s) measured by the kaon monitor; $\mathcal{L}$ is the machine luminosity (cm^{-2}s^{-1}); ϵ_{KM} is the kaon monitor acceptance

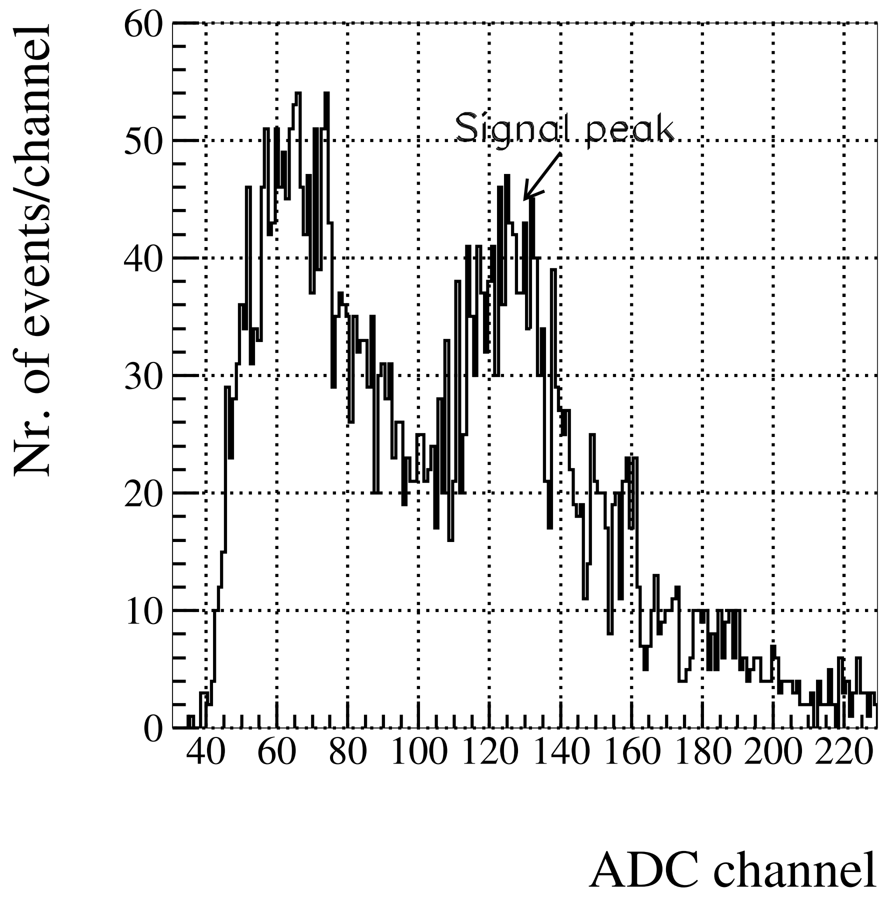

Figure 5: The ADC spectrum for the sum of the 10 runs after the cut in the time-of-flight spectrum, to emphasize only the signal region (regions A and B in the TDC corresponding spectrum of Fig. 4).

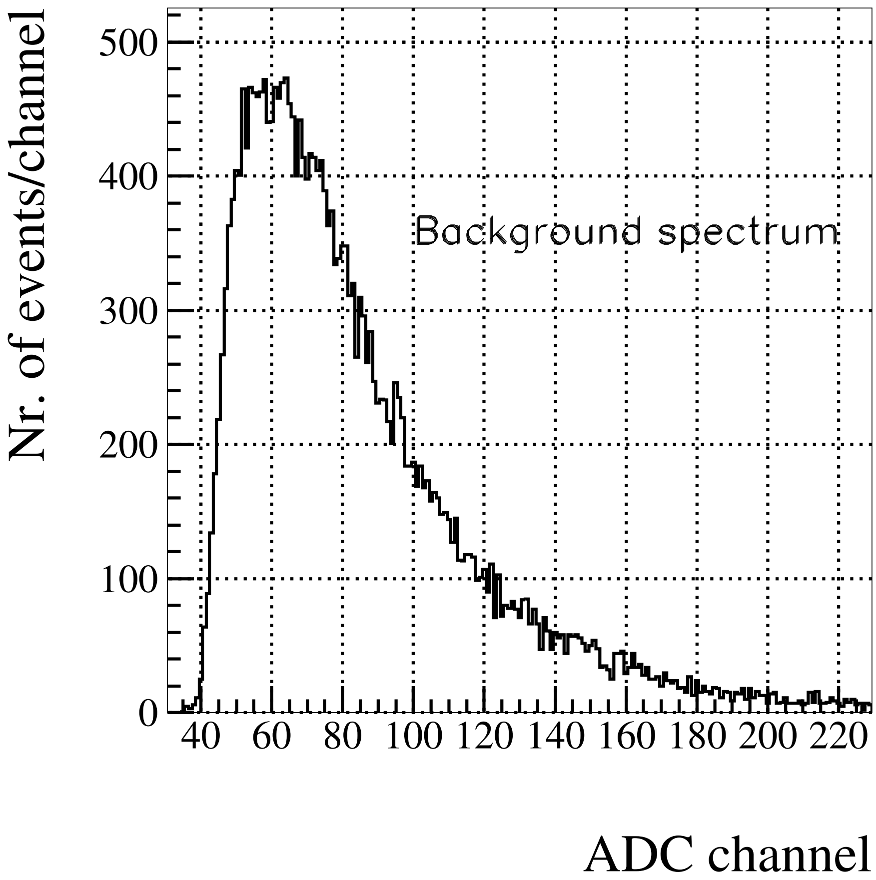

Figure 6: The ADC spectrum for the sum of the 10 runs after the cut in the time-of-flight spectrum, to select only background particles (regions C and D in the TDC corresponding spectrum of Fig. 4).

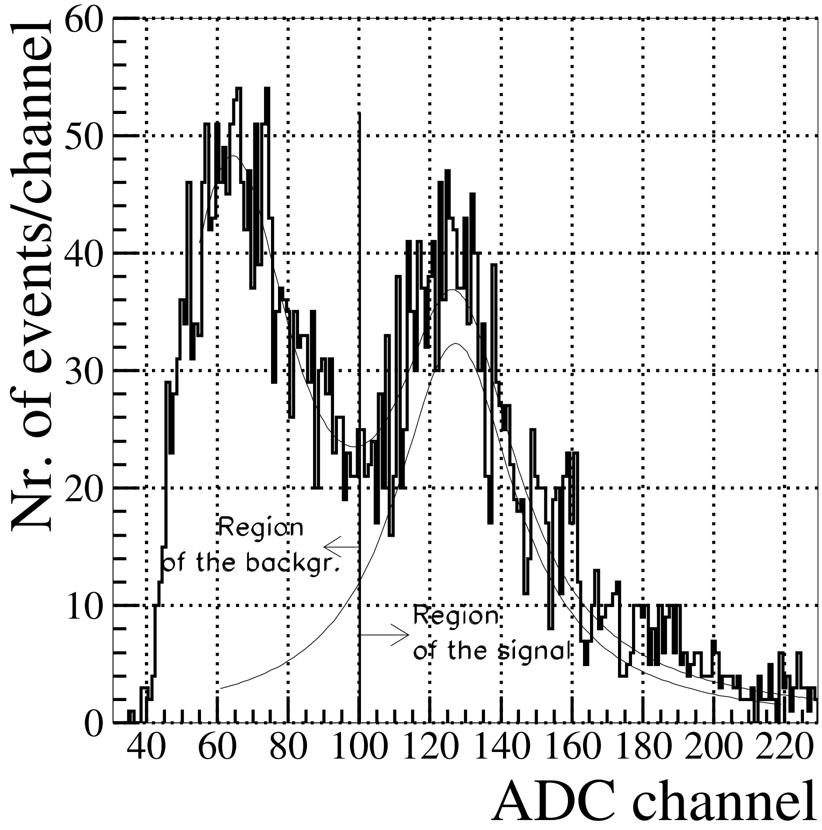

Figure 7: The ADC spectrum for the sum of the 10 runs after the cut in the time-of-flight spectrum emphasizing the signal region, with the fitting curve; the fitting curve of the signal is also shown; the line corresponding to the cut between signal and background regions is as well reported (see text).

evaluated by Monte Carlo; ϵ_D is the detection efficiency; $\sigma(K^+K^-)$ is the production cross section of a ϕ decaying into K^+K^-.

Therefore, by assuming $\epsilon_D = 1$, the luminosity can be expressed as:

$$\mathcal{L} = \frac{R(K^+K^-)}{\epsilon_{KM} \times \sigma(K^+K^-)} \tag{3}$$

Analogously, by considering one or more kaon measurements over a certain time interval, one has:

$$N(K^+K^-)_T = \mathcal{L}_T^{int} \times \epsilon_{KM} \times \sigma(K^+K^-) \tag{4}$$

where $N(K^+K^-)_T$ is the number of kaons recorded in the time interval T, $\mathcal{L}_T^{int}$ is the integrated luminosity delivered in that interval.

Again, the integrated luminosity referred to a certain time interval is given by:

$$\mathcal{L}_T^{int} = \frac{N(K^+K^-)_T}{\epsilon_{KM} \times \sigma(K^+K^-)} \tag{5}$$

Numerically, one has:

- <u>acceptance</u>. The Monte Carlo evaluated acceptance of the two considered scintillators for detecting a K^+K^- pair turned out:

  $$\epsilon_{KM} = 6.4 \cdot 10^{-2} \tag{6}$$

- <u>cross section</u>. The peak production cross section of a K^+K^- pair from a ϕ-decay is [2]:

  $$\sigma(K^+K^-)_{prod} = 2\mu b \tag{7}$$

  This value has to be decreased by a 10% due to the energy spread of the e^+e^- beams in the DAΦNE machine [3]. Therefore, the following value was assumed:

  $$\sigma(K^+K^-) = 1.8\mu b. \tag{8}$$

One can then write in a numerical form all the above equations:

$$R(K^+K^-) = 11.5 \cdot 10^{-32}\mathcal{L} \tag{9}$$

$$\mathcal{L} = 8.7 \cdot 10^{30} R(K^+K^-) \tag{10}$$

$$N(K^+K^-)_T = 11.5 \cdot 10^{-32}\mathcal{L}_T^{int} \tag{11}$$

$$\mathcal{L}_T^{int} = 8.7 \cdot 10^{30} N(K^+K^-)_T \tag{12}$$

It turns out from (9), for instance, that for a luminosity $\mathcal{L} = 1 \cdot 10^{30}$ cm^{-2}s^{-1} the rate of the detected kaons is about 0.1 Hz.

It turns out as well, from (12), that for the period of measurements considered in this report, the overall number of detected kaons, $N(K^+K^-) = 1850 \pm 180$, corresponds to an integrated luminosity:

$$\mathcal{L}^{int} = 16.1 \pm 1.6\ nb^{-1}. \tag{13}$$

This value is not in disagreement with the estimation produced by the DAΦNE luminosity monitor.

In order to obtain from the kaon monitor periodical luminosity information (integrated and averaged over the considered time interval), hence from measurements characterized eventually also by small statistics, a working method was found, based on the information coming from a high statistics data sample built, for instance, as in this case, with a series of measurements. The method takes advantage of the fact that in the summed ADC spectrum after cuts, shown in Fig. 7, two clearly separated regions, the "signal region" and the "background" one, can be identified. A "separation cut" can therefore be put, indicated by a straight line in Fig. 7 and corresponding to a specific channel (channel 100 in this case). Then, by using the fitting function of the ADC spectrum, it could be checked that, in the region beyond the separation line, 90% of events were representing kaon events. By applying this criterium - namely a cut in the ADC spectra above which 90% of events are kaons, a separation cut found by analyzing (and periodically checking) a good statistics data sample - measurements characterized eventually by a poorer statistics could be analyzed. Fig. 8 shows, as example, the ADC spectra of 4 single measurements out of the 10 performed, where the separation line at the channel previously obtained is reported. The numbers of kaons extracted from each measurement by applying the above method are reported in Table 1, together with the corresponding integrated luminosity. The error on the individual luminosity is given by the sum of a statistical error (related with the number of events in the “signal region”) and a systematic error (about 10%), given by the fitting procedure. The values reported in Table 1 do not disagree with the estimation produced by the machine luminosity monitor.

6 Conclusions and perspectives

The experimental work performed on the DEAR kaon monitor during the runs of August-September 2000 was reported. TDC and ADC information was collected and analyzed. A fit procedure to the ADC spectrum referring to the sum of a series of 10 measurements was applied, after having performed cuts on the corresponding TDC time-of-flight spectrum. The overall number of kaons collected in the measurements, after background subtraction, was given. The integrated luminosity value delivered in the corresponding time interval was deduced. A working procedure to extract a periodical luminosity information was found by taking advantage of the fit results obtained in a high statistics data sample.

As can be deduced from the TDC/ADC spectrum of Fig. 3, in order to extract a clean kaon signal, the suppression of background particles, already at hardware level, is compelling. The present analysis demonstrates that also a coupled energy/time-of-flight analysis is not enough for fully accomplishing this aim. Background particles can hit the scintillators at grazing angles, hence depositing energy comparable to that delivered by kaons. Indeed a tail of slow background events contaminates the TDC spectra in the kaon side, as seen in Fig. 4.

In order to suppress such background, the further step will be the installation of 2 + 2 scintillators at the two sides of the beam pipe, before and after the IP, as schematically shown in Fig. 9. Such additional counters will be hit by the background particles travelling sideway along the pipe, but not by kaons, which come only from the IP. Hence, the anticoincidence of the OR of the four new counters with the coincidence of the back-to-back thin scintillators of the kaon monitor will provide much cleaner TDC and ADC spectra. The four anticoincidence scintillators will have each a thickness of 1 cm, a heigth of 10 cm and a length of 8 cm, and will be seen each by a

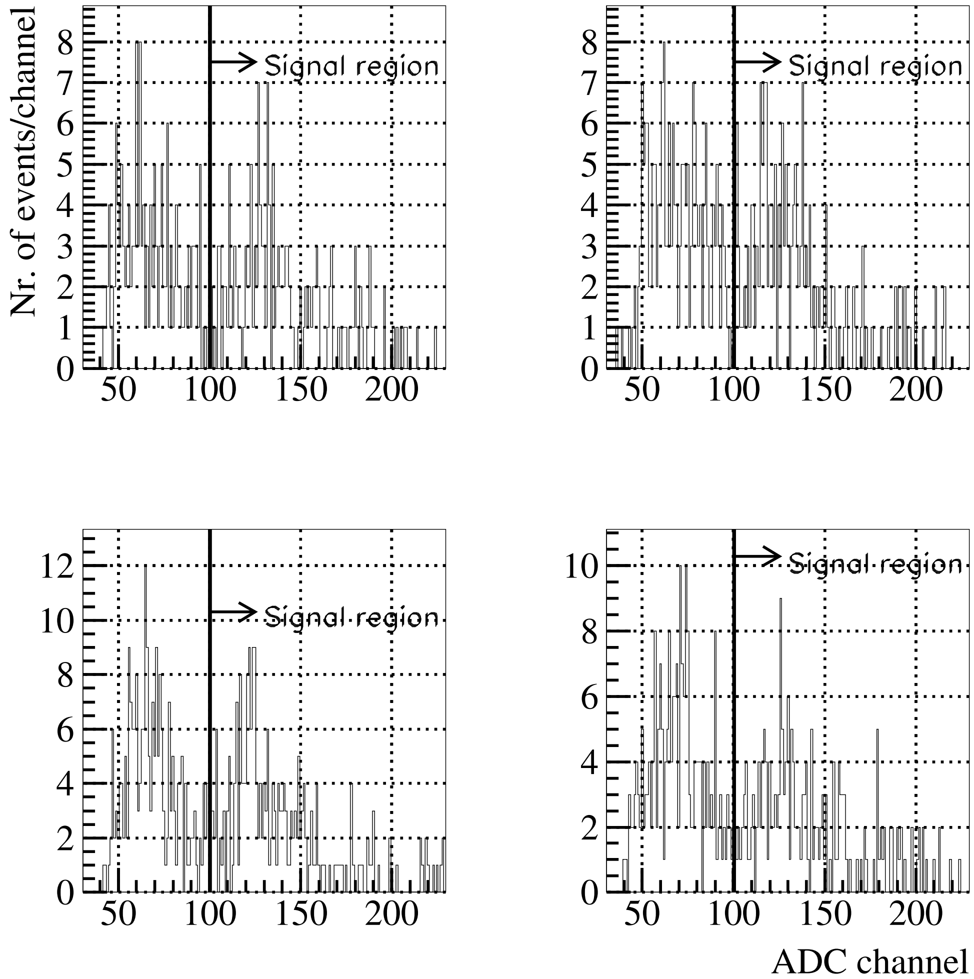

Figure 8: The ADC spectra for 4 individual runs; the line chosen to separate the "signal region" from the "background region" is shown (see text).

Run number	Number of K^+K^- found	Corresponding $\mathcal{L}^{integrated}(\mathrm{nb}^{-1})$
1	142 ± 12	$1.24 \pm 0.10 \pm 0.13$
2	227 ± 15	$1.97 \pm 0.13 \pm 0.20$
3	182 ± 13	$1.58 \pm 0.12 \pm 0.16$
4	176 ± 13	$1.53 \pm 0.11 \pm 0.16$
5	176 ± 13	$1.53 \pm 0.11 \pm 0.16$
6	212 ± 15	$1.84 \pm 0.13 \pm 0.19$
7	176 ± 13	$1.53 \pm 0.11 \pm 0.16$
8	177 ± 13	$1.54 \pm 0.11 \pm 0.16$
9	221 ± 15	$1.92 \pm 0.13 \pm 0.20$
10	179 ± 13	$1.56 \pm 0.11 \pm 0.16$

Table 1: Results for individual measurements: detected kaons and delivered integrated luminosity.

Hamamatsu R1894 phototube, 1 cm diameter. This implementation of the monitor is in progress and will be installed before the next DEAR runs.

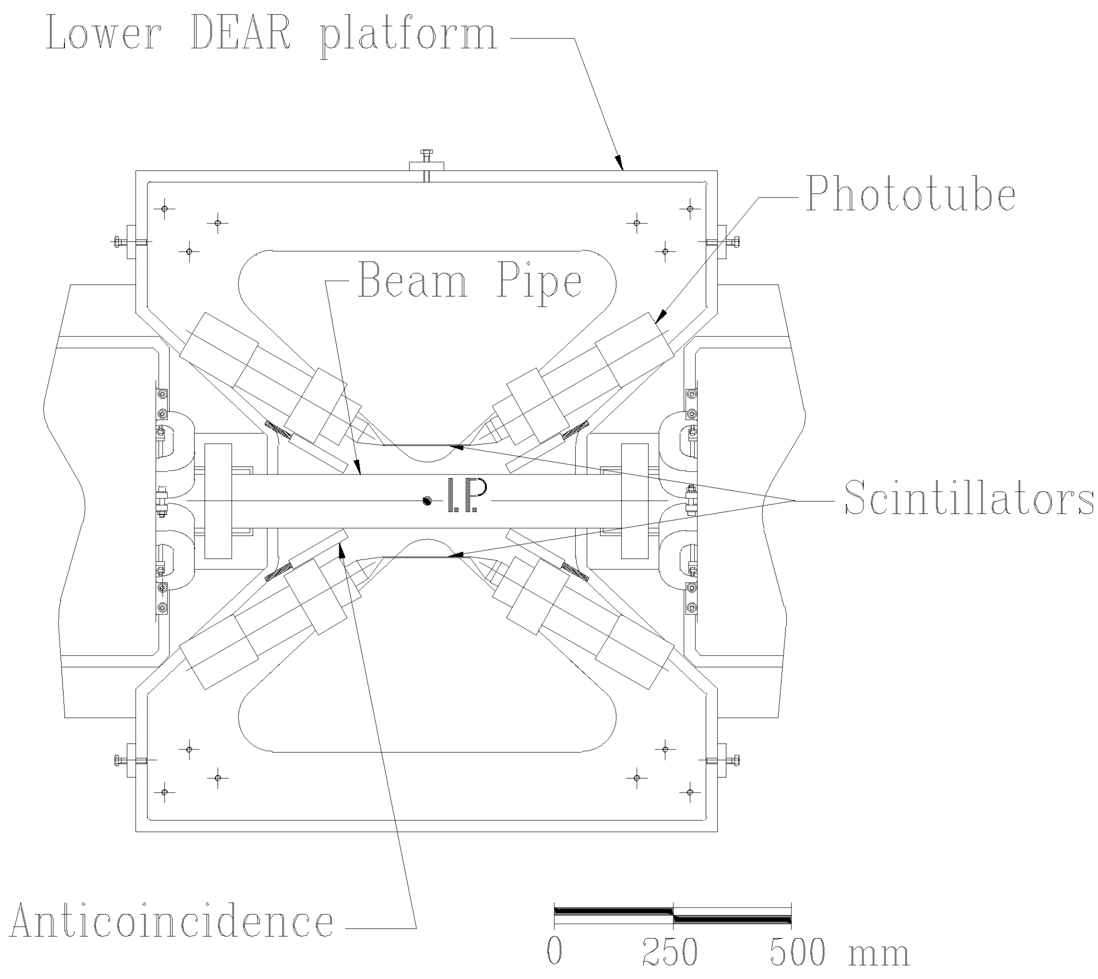

Figure 9: The Kaon monitor setup with the anticoincidence counters.

References

[1] A. M. Bragadireanu *et al.*, "The DEAR Kaon Monitor: results of the first measurements", DEAR Technical Note, IR-16, January 24, 2000.

[2] Review of Particle Physics, The European Phys. Journal **C15**, 1-4 (2000), p. 420.

[3] Review of Particle Physics, The European Phys. Journal **C15**, 1-4 (2000), p. 160.