Influence of the dead time of the counter tube on the pulse distribution

LEP 5.2.03

Related topics

Poisson's distribution; standard deviation; expected value of pulse rate; dead time, recovering time and resolution time of a counter tube.

Principle and task

If the dead time of the counter tube is no longer small with regard to the average time interval between the counter tube pulses, the fluctuation of the pulses is smaller than in the case of a Poisson's distribution. In order to demonstrate these facts the limiting value of the mean value (expected value) is compared to the limiting value of the variace by means of a sufficiently large sampling size.

Equipment

Counter tube, type A, BNC	09025.11	1
Screened cable, BNC, l 750 mm	07542.11	1
Americium-241 source, 370 kBq	09090.11	1
Magnetic base for 09053.88	09053.01	2
Source holder for 09053.01	09053.04	1
Counter tube holder for 09053.01	09053.02	1
Mounting plate R, 32 cm × 21 cm	13001.00	1
COBRA-interface 2	12100.93	1
Counter tube module	12106.00	1
PC COBRA data cable RS232, 2 m	12100.01	1
Softw. COBRA Statis.radioa.decay	14266.51	1

Set-up and procedure

The experiment is set up as shown in fig. 1.

The experiment requires a sufficiently strong radioactive source with the aid of which pulse rates of more than 3000 pulses/s can be reached. These high pulse rates can be reached by means of an α-emitter since the counter tube responds strongly to these particles. The Am-241 source 09090.11 (370 kBq) which must be arranged very closely to the admission opening of the counter tube in very suitable for this purpose.

For the first measurement the radioactive source must be placed as closely in front of the counter tube as possible. Caution: A direct contact between the source and the counter tube might destroy the counter tube!

- Start the program "Statistics of radioactive decay".
- Select the program option <measure> <parameters>.
- Maintain the presettings <background> "subtractnot"; <number of measurements> "1000".
- Selet <function> "$\overline{N}$ σ^2" and set a measuring time of 0.1 s (the shortest time possible).
- Place the radioactive source as closely in front of the admission opening of the counter tube as possible.
- Hit <ok> to close the window.
- Hit <measure> <start> to carry out a short test measurement. The average counting rate is displayed in the status line on the screen. Hit <Esc> to terminate the measurement.

Fig. 1: Experimental set-up: Influence of the dead time of the counter tube on the pulse distribution.

— Select the program option <set> <function> and choose a presetting of the Y-value which is larger than the mean value measured beforehand.

— Activate the program option <measure> <start> (in a very comforatable way simply by means of the <F10> key).

Figure 2 shows a measurement example with an average counting rate of 4600 pulses/s.

Then a series of measurements with larger gaps between the radioactive source and the counter tube, e.g. with smaller average pulse rates, are carried out as described above. If an α-emitter is used as recommended, it must be considered that variations of the distance between the source and the counter tube have a strong influencen on the counting rate. It is thus of great importance to adjust the distance very carefullly in order to obtain the desired pulse rates. In order to be able to compare the results each measurement is asigned to an own window. The windows are then saved on the hand disk (<file> <save>). Figure 3 shows the measurement of figure 1 (window 1) and in addition to that three further measurement examples with approximately 2500 (2), 900 (3) and 110 pulses/s.

Theory and evaluation

As far as the measurements with the pulse rates 4600, 2500 and 900 pulses/s compared in figure 3 are concerned the variance converges towards a distincitively smaller value than the mean value. In the case of 110 pulses/s, however, nearly the same limiting value results for both of them. The fluctuation is clearly smaller for the three measurements mentioned first than it could be expected for a Poisson's distribution. This phenomenon is directly shown in figure 4. This figure shows ths same series of measurments as figure 3, but in this case in the form of a statistical distribution together with the theoretical Poisson's distribution (<graphichs> <statistics> <collection>: "3" <curve>: "Poisson") corresponding to the calculated mean value. The deviations between the limiting values of variance and mean value show that due to the limited resolving time t_{ress} of the counter tube a part of the pulses could not be counted. In fact, the measured pulses ought to be corrected to a bigger value. The resolving time is slightly longer than the so-called dead time of the counter tube. The dead time of the counter tube used for this experiment is in the order of about 0.1 ms. The probability that a pulse directly follows an already counted pulse within the resolving time and thus cannot be counted is:

$$P = 1 - e^{-\dot{N} \cdot t_{res}} = \dot{N} \cdot t_{res} \quad \text{for} \quad \dot{N} \cdot t_{res} << 1.$$

In the case of a resolving time of 0.1 ms and an average counting rate of $\dot{N} = 100\ s^{-1}$, for instance, this probability is in the order of magnitude of 1 %, in the case of $\dot{N} = 1000\ s^{-1}$, however, it already reaches about 10 %.

This error of measurement which is due to the dead time of the counter tube can have a strong falsifying effect, e.g. when the dependence of the radiation intensity of a γ-emitter on the distance between the source and the counter tube is measured, especially in the case of short distances. The comparison of the limiting values of variance and standard deviation described in this experiment is a reliable indicator for such counting erros.

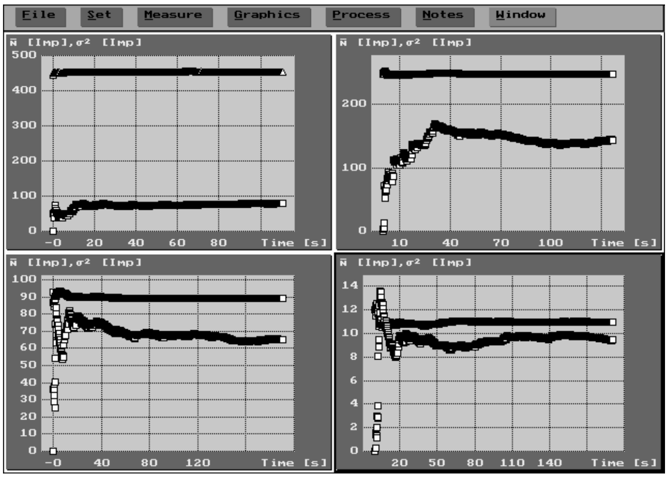

Fig. 3: Mean value and variance in the case of average pulse rates of 4600, 2500, 900 and 110 pulses/s.

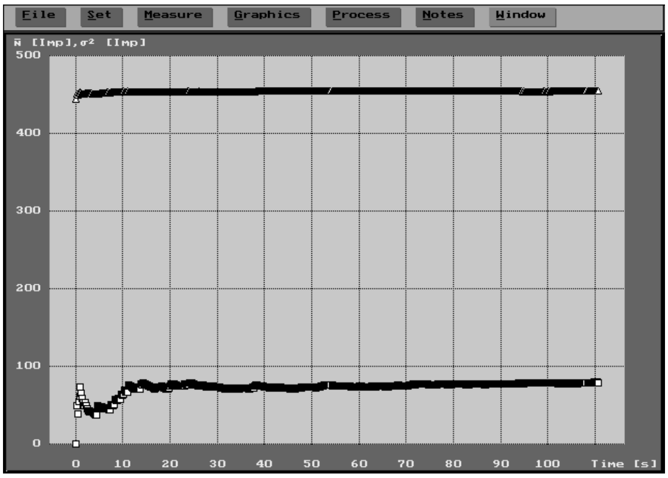

Fig. 2: Mean value (top) and variance in the case of an average pulse rate of 4600 pulses/s.

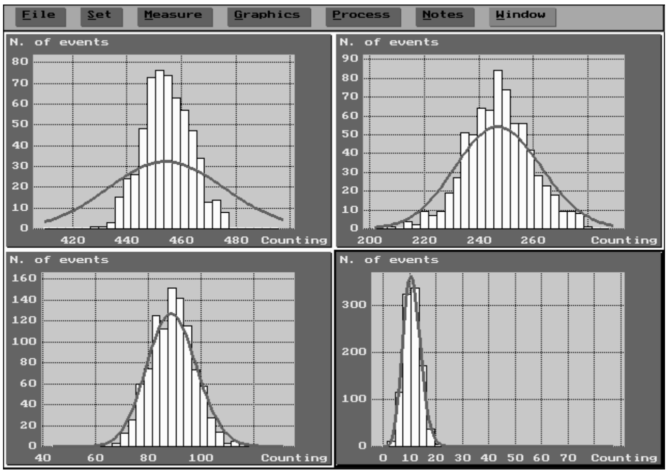

Fig. 4: Statistical distribution for average pulse rates of 4600, 2500, 900 and 110 pulses/s compared to the theoretical Poisson's distributions.