JOINT INSTITUTE FOR NUCLEAR RESEARCH, DUBNA

Report 13-6088

A SYSTEM FOR STABILIZING THE SPECTROMETER CHANNEL OF A ČERENKOV COUNTER

V.A. Kramarenko and M.N. Khachaturyan

Dubna 1971

Translated at CERN by B. Hodge
(Original: Russian)
Not revised by the Translation Service

(CERN Trans. Int. 72-2)

Geneva
February 1972

In certain accelerator experiments aimed at discovering rare decays, in which the particle energy is measured by means of scintillation or Čerenkov detectors incorporating photomultipliers, it is necessary to ensure that measurement of the pulse-height spectra remains stable for lengthy periods (of the order of a month).

An analysis of the pulse-height instability in the measurement channels of such detectors shows that the main contributory cause of this instability is fluctuation in the amplification factors of photomultipliers. In particular, when the measurement of γ-quanta energies is effected by means of a Čerenkov shower-type total absorption spectrometer, (having a resolution of 10%)[1], the instability in the results, owing to the photomultipliers, is as high as 10% (Fig.1a) when the stability of the electronic equipment is $< 1\%$ (Fig.1b). This drift in pulse-height is comparable with the spectrometer's resolution, and can seriously compromise measurement accuracy.

In order to stabilize the pulse-height of the spectrometer, use is made of a reference luminous burst of α-particles of ^{243}Am having an energy of 5.48 MeV, in a Cs I (Tℓ) crystal measuring 10 x 10 x 0.2 mm. Instability of light detectors of this type may be caused by variations in the light yield of the crystal as a function of temperature[2].

The work involved investigations into the unstable nature of the light yield from a crystal of Cs I (Tℓ) as a function of temperature. This dependence is shown in the graph of Fig.2a. As can be seen from the figure, the light yield of the crystal remains virtually stationary in the temperature range between 18° and 90°C. Fig.2b shows, for comparison, the temperature instability of the ФЭУ-49 photomultiplier on which measurements were made.

The light detector used provides a strictly constant flash of light which is independent of external factors. A disadvantage of this reference source is that there is no way of controlling the pulse height of the signal. However, the cyclic nature of the accelerator's operation and of the stabilization system which is switched on between the acceleration cycles provides a means of controlling the pulse height of the reference signal from the α - source; how this is achieved is described below.

Let us examine the block diagram of the spectrometer channel of a Čerenkov total absorption spectrometer (Fig.3). The light from the Čerenkov detector unit, Č, is converted by the photomultiplier FEU-49 into an electrical signal, which is amplified by a factor of 6 by the linear amplifier unit (LA) /3/. At the LA output, the pulse is attenuated by a factor of 6. The signal is then integrated (unit 1), transmitted through the linear gates (LG unit) and analysed by an analog/digital converter (ADC). After this, a stabilizing unit corrects the amplification in the channel to match the reference α-source.

The amplification margin enables a passive attenuator, A, to be inserted at the LA output, control of the attenuation being effected during the intervals between the accelerator cycles. The switching control in the attenuator unit was provided by an "RSM"-type relay. During the acceleration cycle (1 second) a working attenuation by a factor of 6 of the signals under examination is introduced. During the interval between accelerator cycles, a 1 to 6 times attentuation is introduced for the reference signals, depending on the values of the resistors in the attenuator.

It should be noted that the stability of the attenuation introduced may be affected by a change in the resistance of the relay contacts and by temperature-induced variations in the values of the resistances in the separator, since these components are not included in a feed-back circuit. In the case of the relays selected, the long-term variation in the resistance of a pair of contacts does not exceed 0.04 , which corresponds to an amplification instability of $\frac{0.04}{50}$ = 0.8%. Instability owing to the thermal

co-efficient of resistance (TCR) of the resistors may be reduced by using in the separator BLP-type resistors which have a TCR of 0.1% per 1°C.

In order to stabilize the amplification factor of the spectrometer channel, it was decided to use an analog/digital stabilizing system [4], which compares the intensities of the particles in two digital "windows" on the slopes of the reference α - spectrum (see Fig.4a). If the α -spectrum moves in relation to the digital windows, the unbalance signals which are produced are converted by the stabilizing system into an analog correction signal, which controls the conversion factors of the ADC. Let us examine the operating logic of the stabilizing unit in Fig.4b.

A series of pulses from the ADC output produces in the address register (scaling circuit) the digital code for the signal which is being analysed. The triggers of the address register are connected to three code-comparison circuits: SSK-1, SSK-2, SSK-3 [5]. If the code of the signal being analysed exceeds the code given by the corresponding SSK circuit, the following signals appear at the circuit outputs:

b_1 - lower spectrum limit N_1 exceeded;

b_2 - middle spectrum limit N_2 exceeded;

b_3 - upper spectrum limit N_3 exceeded.

The logic circuit 1 $(b_1 \cdot \bar{b}_3) = a_2$ separates the code located in the interval (N_1, N_3). The signal transmitted (a_2) is fed into circuit II and authorizes the transmission of the signal "End of series" from the ADC. The operating logic of circuit II is $(a_1 \cdot a_2) = c$.

If the code of the signal which is being analysed comes within the limits (N_1, N_2), there is no (b_2) signal, and the signal (c) passes through circuit III $(c \cdot b_2) = c_1$, causing the capacitor to be charged with a 6 mA DC current in a time of 100 microseconds. The potential on the capacitor increases by 2 mV and corrects, by means of a composite emitter-repeater (EP), the conversion factor of the ADC by + 0.02 of a channel.

If the code of the signal which is being analysed comes within the limits (N_2, N_3), the signal (c) passes through circuit IV ($c \cdot b_2$) = and, in a similar manner, the ADC is corrected by - 0.02 of a channel.

If the code of the signal which is being investigated does not reach the digital "windows" (N_1, N_2) and (N_2, N_3), then it will have no corrective effect on the coder.

For a reference source which has an intensity of about 150 particles/second, and for a channel whose amplification fluctuates erratically, amplification is restored at a speed of 2 to 3 channels per second. Discharging of the capacitor as a result of leakage currents, in the absence of any reference signals over a period of 10 seconds, corresponds to 1 channel.

The stabilizing system corrects the variation in the amplification in any unit of the spectrometer channel before and after the controlled attenuator. This can be seen from Fig.5, where the dashed lines indicate the corrective effect of stabilization when there is a variation in the photomultiplier's amplification factor. In this figure, a is the reference peak, e^- is the stabilized peak.

A check on the operation of the stabilization system with the reference α - source was carried out on electrons (4 GeV), in the form of an addition to the π^- meson beam of the JINR synchrophasotron. The results are shown in Fig.6. The 10% drop in pulse height over a period of 17 hours, (the unbroken part of curve a), is corrected by the stabilizing system to within 0.5% (curve b). When the amplification factor of the photomultiplier varies from + 28% to - 17% (discontinuous part of curve a), the variation in the stabilized signal does not exceed 1%.

The above stabilizing system was used in a two-channel Čerenkov mass spectrometer[1] for experiments in connection with studies on the production cross-section of η -mesons in the region of small momentum transfers /6/.

In conclusion we wish to take the opportunity of thanking S.G. Basiladze, E.G. Imaev and L.P. Chelnokov for their help in this work.

References

1. M.A. Azimov, A.S. Belousov et al. Preprint, E13-2971, Dubna, 1966; M.N. Khachaturyan et al. Nucl.Instr. and Meth., 51B, No. 2, 309-314 (1967).

2. E.L. Stolyarova et al. Material for the Third Co-ordination Conference on Scintillators (1960), issue 2. Published by KhGU, Kharkov, page 99, 1963.

3. V.A. Aref'ev et al. JINR Preprint 13-5447 Dubna 1970.

4. V.I. Prikhod'ko, V.G. Tishin. JINR Preprint R-2707 Dubna 1966.

5. L.P. Chelnokov. JINR Preprint, 13-4720 Page 251, Dubna 1969.

6. J. Hladky, A.M. Baldin et al. Phys.Lett., 31B, No.7, p.475-477 (1970).

Manuscript received by Publishing Department

14 October 1971.

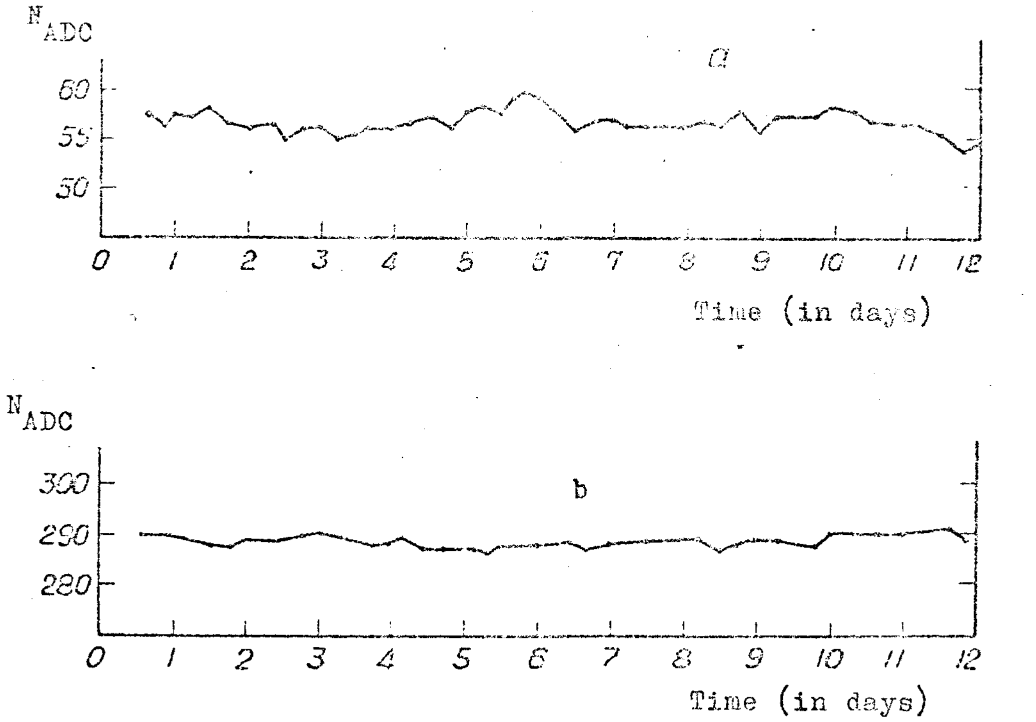

Fig. 1. Instability of the amplification factor of the spectrometer channel caused by; the photomultiplier (a), the electronic equipment (b).

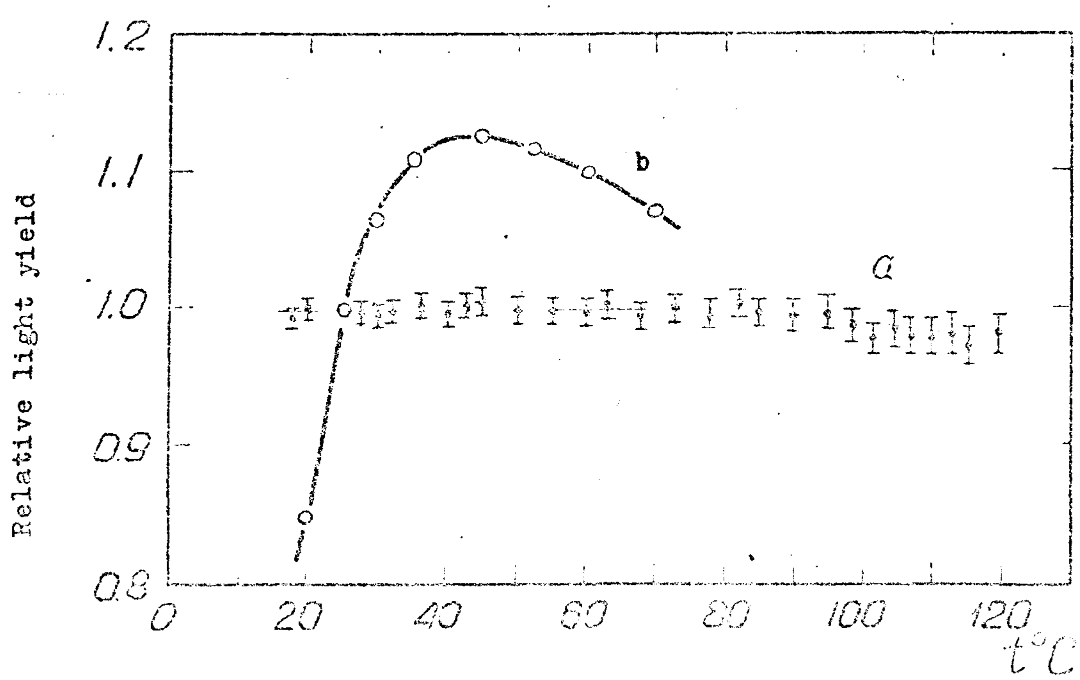

Fig. 2. (a) Temperature-induced instability of the light yield of a crystal of Cs I (Tl); (b) temperature-induced instability of the photomultiplier FEU-19.

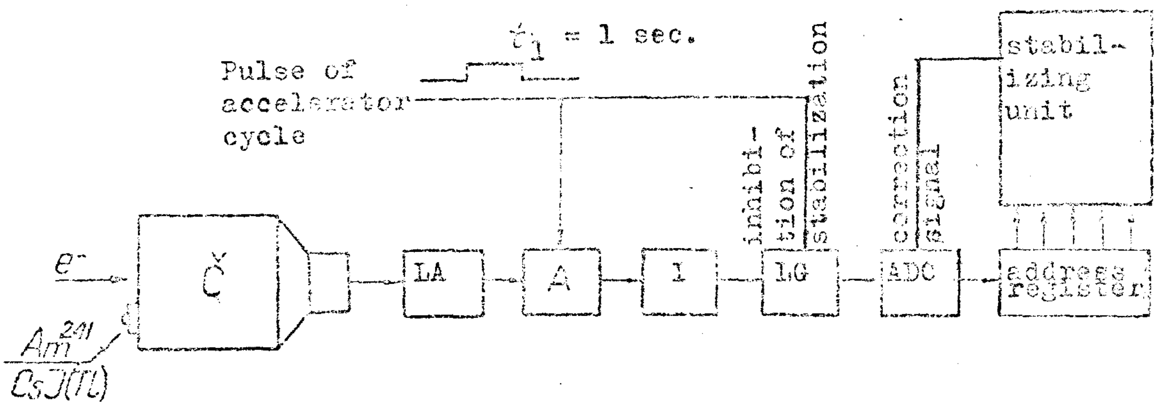

Fig. 3. Block diagram of the spectrometer channel of the Čerenkov counter.

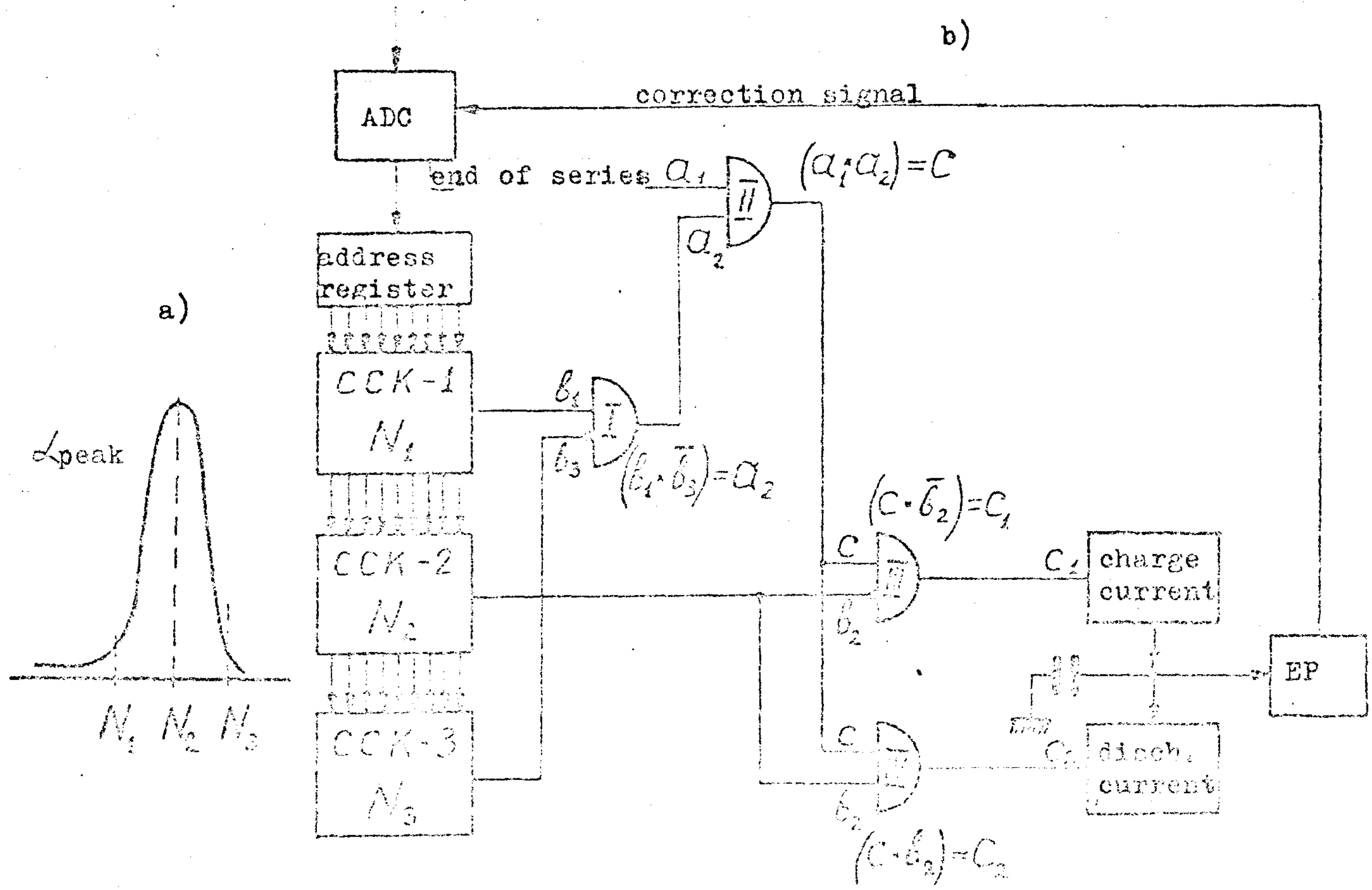

Fig. 4. Operating logic of the stabilisation unit.

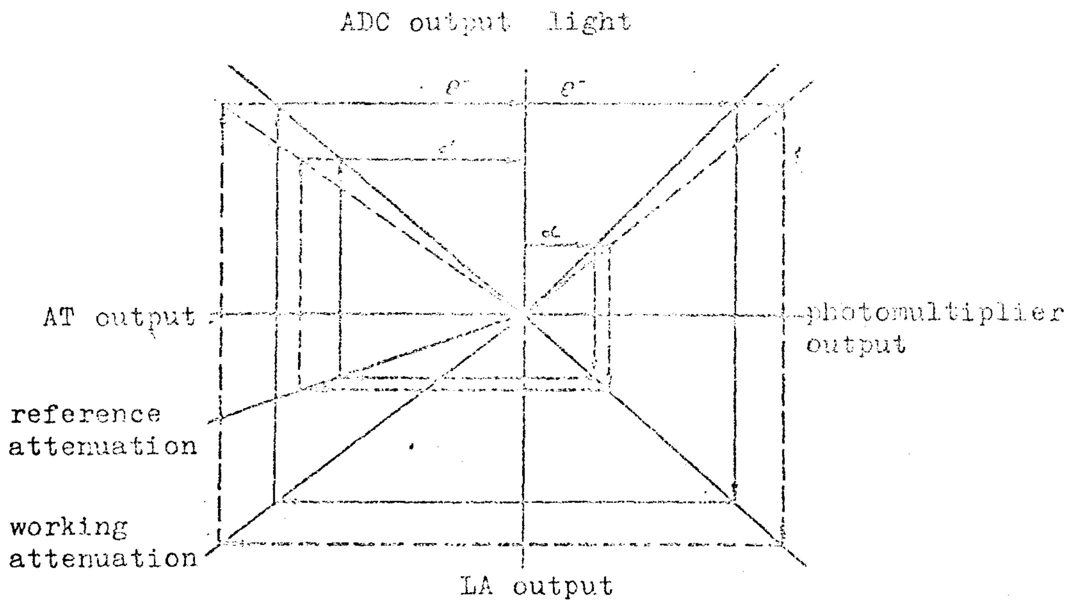

Fig. 5. Diagram of the transmission coefficients and illustration of the corrective action of the stabilization system during variations in the amplification coefficient of the photomultiplier (dashed lines).

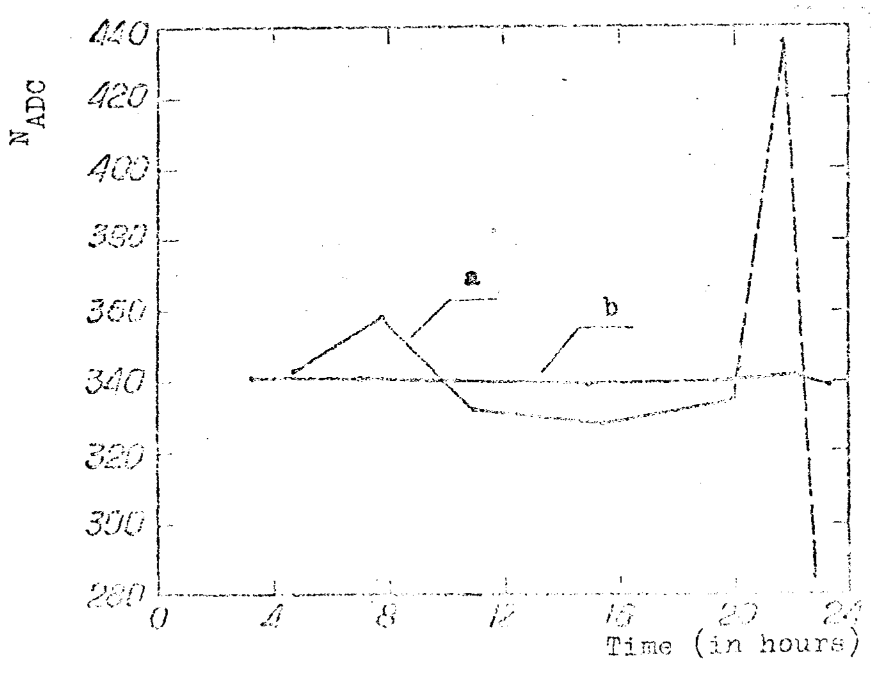

Fig. 6. Stability of the position of the electron peak: (a) without stabilization and (b) with stabilization.