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CONSTRUCTION OF A SCINTILLATION COUNTER TELESCOPE FOR THE REGISTRATION OF THE MESON COMPONENT OF COSMIC RAYS

by

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Abstract

A scintillation counter telescope has been constructed at the Department of Physics, University of Oulu, to register the hard component of cosmic rays. It is a standard equipment for cosmic ray measurements consisting of a so called wide angle telescope, four cubical telescopes and east-west, west-east, north-south and south-north directional telescopes. Integrated circuit electronics has been applied. The average counting rates are about $1.07 \cdot 10^6$ particles per hour (p.p.h.) for the wide angle telescope, $1.61 \cdot 10^5$ p.p.h., for cubical telescopes and $9.54 \cdot 10^4$ p.p.h. for directional telescopes. The soft component of the radiation has been absorbed by a 10 cm layer of lead.

1. *Introduction*

The continuous measurements of cosmic ray particles at sea level are nowadays mainly carried out using neutron monitors and mesontelescopes. The former equipment registers the soft component of cosmic rays and the latter one the hard component, which consists mainly of μ-mesons. At the Department of Physics, University of Oulu, a neutron monitor and a mesontelescope have been constructed earlier [5, 8]. The operation of the Geiger-Müller mesontelescope, however, ceased at 1966.

The requirements of the new equipment to replace the closed one were, to have a good stability and reliability and a high counting rate in order to obtain as small statistical fluctuations as possible. In scintillation detectors the time resolution is very good and there are no uneffective areas in the detection planes as there are when using Geiger-Müller tubes. These properties of the scintillation detectors are responsible for the high counting rate. The stability of the integrated circuits is better than that of the conventional electron tubes or transistor circuits. Therefore an equipment with scintillation detectors and integrated circuits was decided to construct.

2. *Detailed description of the instrument*

a) Environmental location of the telescope

The telescope is located in a wooden, one floor building, the roof of which is lightly constructed. Hence the cosmic ray absorption of the building is negligible.

In the telescope there are eight squared detector plates (Fig. 1). They form two planes, between which a lead absorber is located. Its thickness

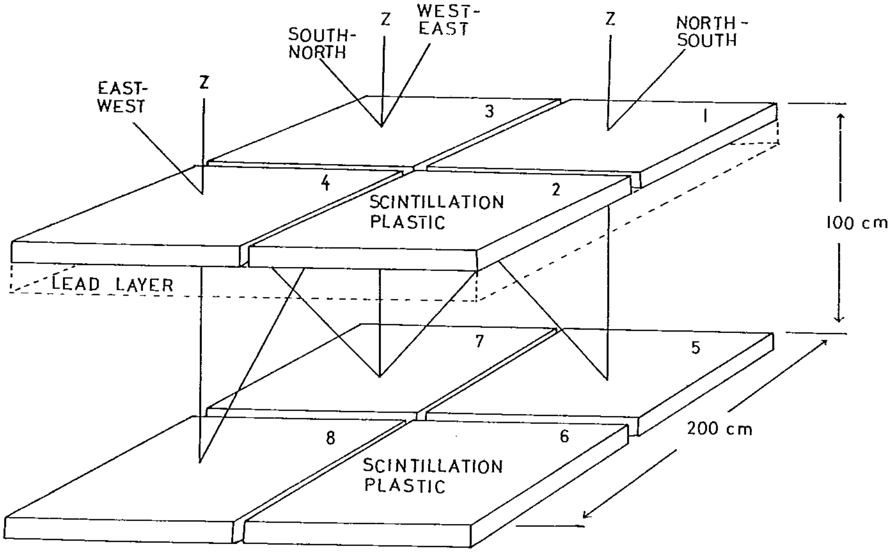

Fig. 1. Geometry of the scintillation counter telescope.

is 10 cm and weight about 4700 kg. This mass needs a strong base. The base is constructed from steel supports mounted on massive concrete beds.

The photomultiplier tubes and the electronics of the telescope require very constant temperature for a faultless operation. Therefore the temperature of the room has been stabilized. Because of the large temperature variations of the local climate it was necessary to use both the heating and cooling facilities. A control system which regulates the temperature better than ± 0.4°C has been employed. Under these circumstances the operation of the telescope has been satisfactory during both summer and winter times.

b) Scintillation detectors and electronics

The telescope consists of the scintillation detectors, the coincidence logic and the registration unit. The block diagram of the entire system is illustrated in Fig. 2.

Each of the detectors consists of the scintillation material, the light collector, the photomultiplier tube, the amplifier, the pulse height discriminator and the voltage supplies with a voltage divider.

— *Scintillation material*

The scintillation material used in the telescope is NE102 scintillation plastics [6]. In each of the detectors there are four slabs the sizes of which are 50 × 50 × 5 cm^3. They form one uniform detector plate of one square meter. The detector plates are on the bottom of light tight wooden boxes. In order to obtain a good light collection and diffuse reflections the upper corners of the boxes have been replaced by four screens of equilateral triangles and finally the inner surfaces have been painted white. The geometry and light collection is the same as in [7]. The scintillators are not polished and have been painted white with a high refractive paint on the surfaces against the walls and floor of the box. Polyvinyltoluene mixed with p-terphenyl and 2, 2′ — p-phenylene bis — (5-phenyloxazole) is the basic material of these scintillators. The decay time of the scintillation events is about 3 ns and the maximum light output is in the proximity of wavelength 4250Å.

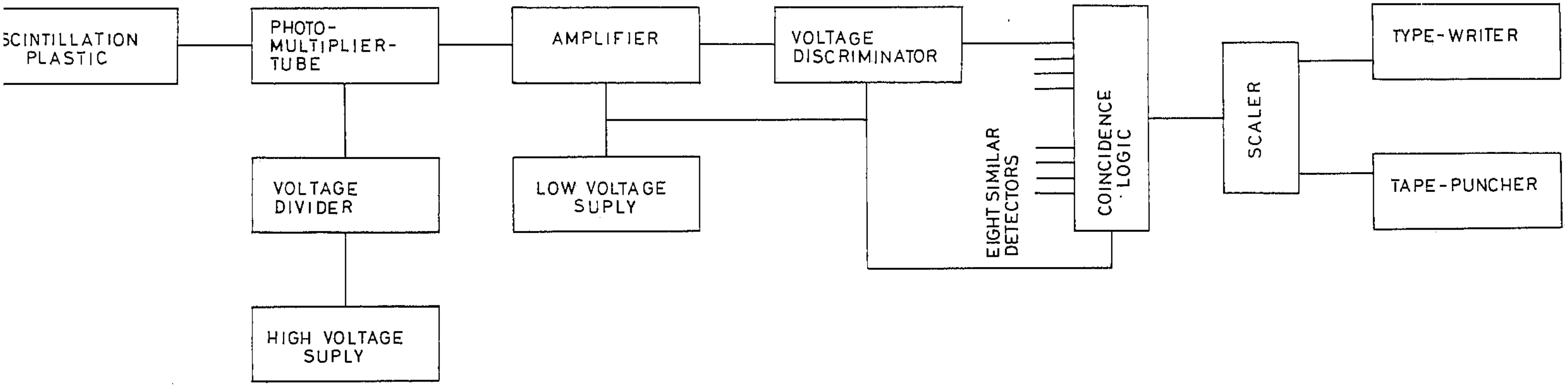

Fig. 2. Block diagram of the scintillation counter telescope.

— *Photomultiplier tubes*

The photomultipliers are the Dumont type 6364 [1]. They have CbScO cathodes, diameter 10 inches, and multiplier stages of ten AgMgOCs dynodes. The maximum quantum efficiency of the photocathode lies on the wavelength region of 4300Å. Hence the spectral response of the tubes is comparatively well matched to the fluorescent emission of the NE102 scintillation. The distance between the photocathode and the scintillation plastic is 63 cm. The tubes have been mounted on the roofs of the boxes so that they see most of the scintillation light coming straight from the plastic.

— *The electronics* consists of the voltage divider, amplifier, pulse height discriminator, coincidence logic, and scaler. The voltage divider has been constructed using mainly resistors of 150 kohm and capasitors of 470 pF. These values of the components have been chosen so that reasonably sharp output pulses were obtained [3].

The amplifier and the pulse height discriminator as well as the coincidence logic were constructed by means of integrated circuits [3, 4]. The logic operates so that nine two-fold and two four-fold coincidences are obtained. Using the symbols described in Fig. 1 and the Boolean expressions the former ones are as follows:

The wide angle $(1 + 2 + 3 + 4) \cdot (5 + 6 + 7 + 8)$, the cubical $1 \cdot 5$, $2 \cdot 6$, $3 \cdot 7$, and $4 \cdot 8$, and the directional north-south $1 \cdot 7 + 2 \cdot 8$, south-north $3 \cdot 5 + 4 \cdot 6$, east-west $2 \cdot 5 + 4 \cdot 7$, and west-east $1 \cdot 6 + 3 \cdot 8$.

The four-fold coincidences $1 \cdot 2 \cdot 3 \cdot 4$ and $5 \cdot 6 \cdot 7 \cdot 8$ have been introduced to measure small showers and spurious counts.

The recordings are printed once per hour by a typewriter and a tape puncher.

3. *Characteristics*

a) Response of a particle detector as a function of the distance of the particle track from the center of the scintillator

In order to obtain some information about the response a small scintillator ($10 \times 10 \times 5$ cm^3) was moved step by step across the bottom of the detector box. The counting rates were measured in different loca-

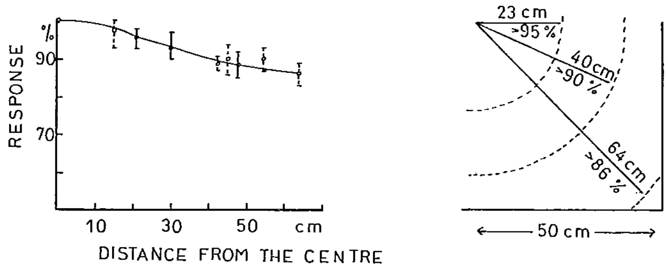

Fig. 3. Response of a particle detector as a function of the distance of the particle track from the center of the scintillator.

tions of the detector. The results are illustrated in Fig. 3. The response decreases from 100 to 86 per cent when moving from the center to the corners.

b) Pulse height distributions

In order to match the amplifiers and the photomultiplier tubes and to control later the operation of the units the integral and differential pulse height distributions were measured for each of the detectors [4].

The integral distributions were obtained by varying stepwise the discrimination level and measuring the counting rates. The differential distributions were calculated from these measurements. In the differential distributions the noise pulses and the scintillation pulses can be seen apart from each other. As an example some distributions are illustrated in Fig. 4. The actual discrimination levels have been adjusted so that the counting rate of a single detector is without the lead absorber about 10800 and with the absorber about 8900 particles per minute.

c) Plateaus

The counting rate of each detector as a function of the photomultiplier voltage has been measured as well as the counting rate of each cubic telescope and the wide angle telescope. The plateaus of the photomultipliers begin at about 1150 V, and the operation point has been set to 1200 V. The average change of the counting rate of a *single* detector is 0.11 %/V around the point of operation. The plateau curve of a *single cube* and that of the *wide angle telescope* are illustrated in Fig. 5. The slopes of the curves at 1200 V are 0.06 %/V and 0.05 %/V.

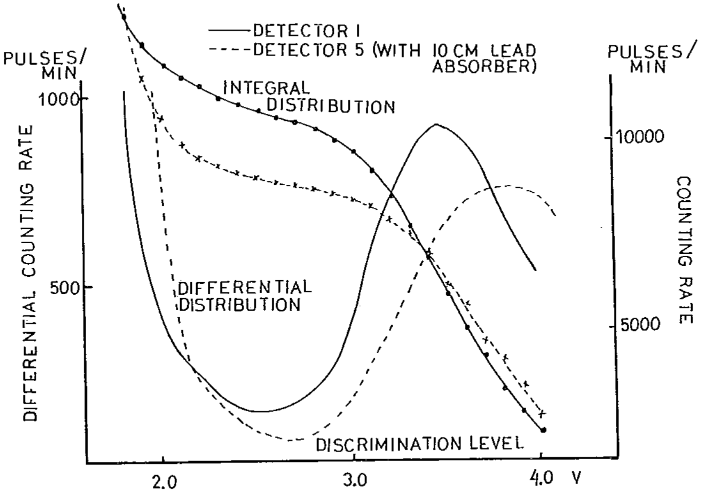

Fig. 4. Integral and differential pulse height distributions of the detectors 1 and 5.

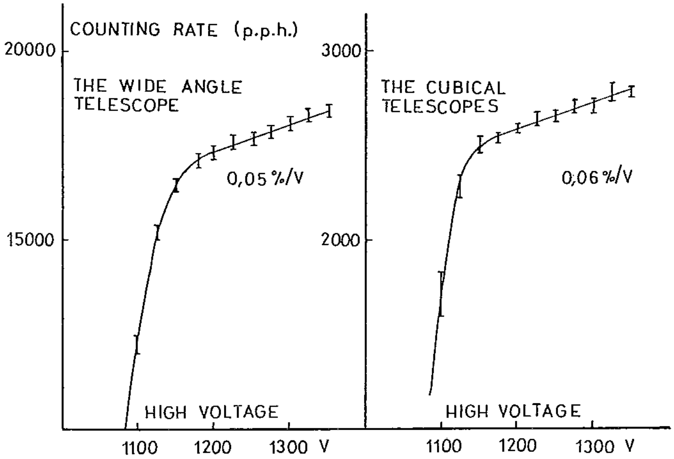

Fig. 5. Plateau curves of the cubical telescopes and the wide angle telescope.

d) Recording capacity and statistical fluctuations

The telescope has operated from the first of August 1968. From the data of the first operation year the following averages have been calculated:

The wide angle telescope records on the average 1070000 ± 34500 p.p.h., the cubical telescopes on the average 161000 ± 4000 p.p.h., and the directional telescopes with deviations of ± 2400 p.p.h. from north 93500 p.p.h., south 97400 p.p.h., west 94700 p.p.h., and east 95900 p.p.h.. The above mentioned deviations are large because the averages and their deviations have been calculated from the data, which include all variations arising from the pressure variations, atmospheric disturbances and changes in the primary radiations.

The recorded intensity of the cosmic radiation has some statistical fluctuations. These fluctuations may be partly originated from the recording instrument. If m is a measured averaged number of particles in a time T, then the statistical error of a counting instrument can conventionally be expressed by the standard deviation $\delta = \sqrt{m}$, the probability that the true counting rate lies in the interval $\frac{1}{T}(m \pm \sqrt{m})$ is 0.68, [2].

From the counting rates of the meson telescope the following standard deviations can be calculated:

— the wide angle telescope $\delta = 1030$ p.p.h.
— the cubical telescopes $\delta = 400$ p.p.h.
— the directional telescopes $\delta = 310$ p.p.h.

In Fig. 6 the intensity during a typical period of four days is illustrated. One can see that during a quiet time the fluctuations are between the limits of ± δ with the probability of 0.68.

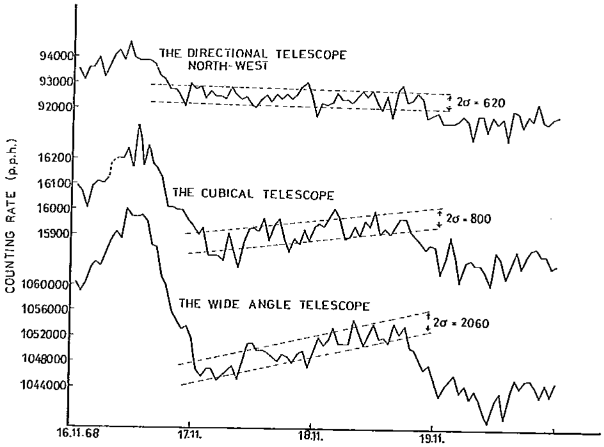

Fig. 6. Statistical fluctuations of cosmic ray data registered by the scintillation counter telescope.

e) Spurious counts and dead time losses

The problem of spurious counts becomes important because of the high counting rate of each single detector in counting two-fold coincidences. The probable amount of spurious coincidences per unit time for two-fold coincidences is

$$n_{12} = 2\, n_1 n_2 T\ .$$

T is the duration of a discriminator output pulse and n_1 and n_2 are the amounts of counts of single detectors [2]. For the telescope described here the following amounts of spurious coincidences can be calculated:

— the cubical and directional telescopes
$n_{12} = 42$ coincidences per hour,

— the wide angle telescope
$n_{12} = 670$ coincidences per hour.

In both cases the amounts of the spurious counts are smaller than the statistical fluctuations and very small compared with the respective counting rates. Therefore they cause no data corrections.

In the coincidence counting the counting losses can be separated into two parts:

— the losses due to the dead times of the detectors
— the losses due to the coincidence logic and the scaler.

In scintillation detectors the typical dead times are of the order of some hundreds of nanoseconds. The dead times of the coincidence circuits and the scaler are some nanoseconds only. The common counting losses caused by the above mentioned sources have been calculated to be of the same order or less as those of the spurious counts.

Because counting rates are increased by the spurious counts and decreased by the counting losses there are no reasons for corrections in the data.

4. *Conclusion*

During the time the scintillation counter telescope has been in operation only few disturbances and interruptions have occured. They have nearly in all cases been caused by power failures. The reliability of the electronics has been very good, too. Two photomultiplier tubes have been changed. It is apparent that the life of photomultipliers will cause small difficulties in a long life operation, because the life times of the tubes are rather short, according to the manufacturer only some thousands of hours. The obsolescence of the tubes is rather slow and linear with time. Therefore it can be taken into consideration when using data.

The mesontelescope has been used and will be used for example to study the correlations between the cosmic ray meson and neutron intensities and the meteorological disturbances. The periodic time variations will be studied, too.

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