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HIGH RESOLUTION TIME-OF-FLIGHT MEASUREMENT WITH LARGE AREA COUNTERS

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In experiments on particle-antiparticle production by electron positron colliding beams, cosmic rays give a considerable contribution to total background. In particular, a large fraction of the cosmic rays which pass through the interaction region cannot be distinguished from events produced by interaction between the two beams, even when spark chamber pictures are used.

A time-of-flight measurement between two counters of the experimental set up, separated by a distance d as shown in fig. 1, allows us to distinguish cosmic rays from pairs of charged particles produced by an annihilation event. This time-of-flight is of the order of some ns ($\approx 4 \div 8$ ns, $1 \lesssim d \lesssim 2$ m) when a cosmic ray passes through the two counters, whereas it is zero for two charged particles produced in the interaction region.

When large scintillation counters are used, the main difficulty in measuring and distinguishing these time intervals arises from the finite transit time of light in scintillators. By properly applying double time-of-flight methods[1–3]) it is possible to minimize these effects. In this paper we show results of time-of-flight measurements between two $100 \times 100 \times 2$ cm^3 scintillation counters. A time resolution of ± 0.7 ns has been obtained. A method to distinguish direction (right ⇄ left, up ⇄ down) of cosmic rays is proposed.

1. Experimental apparatus

Fig. 1 shows the apparatus, used for measurements; F and G are two $100 \times 100 \times 2$ cm^3 scintillation counters. They are placed symmetrically on either side of the beam interaction region, which has been simulated by a $10 \times 10 \times 1$ cm^3 scintillation counter C. Each scintillator is viewed by two symmetrical pairs of 56 AVP photomultipliers. Light pipes are of the triangular shaped kind.

Fig. 2 shows the scheme of the logic: F_R, F_L are pulses obtained by mixing the output from the pair of tubes on the right or left side of the counter F, the same for G_R and G_L. Time to pulse height converters (CTA1, CTA2)* are gated by coincidence (F, G, C) and, as is shown in the scheme, they measure the time differences Δt_1 (between F_R and G_L) and Δt_2 (between F_L and G_R).

Maximum efficiencies of F and G, for minimum ionizing particles, have been chosen for a value of voltage threshold of D_1, D_2, D_3, D_4 about 2.5 times threshold of corresponding D′ ($v_s \approx 0.2$ V). This procedure reduces the shift of time delay versus input amplitude to D′ to a small value and enables us to use a dc hv supply not too high in value ($2500 \div 2600$ V) for the 56 AVP photomultipliers.

* The time to pulse height converter has been described in [4]). The actual circuit has been derived from it with small modification in the start-stop circuit and by using a fast recovery monostable univibrator as gate stretcher. A dc coupling in the output circuit avoids dc level shifting when working at maximum repetition rates (≈ 10 Mc/sec).

2. Data analysis

Voltage V_Σ corresponding to $\Delta t_1 + \Delta t_2$ (fig. 2) is recorded by a multichannel analyzer (Laben mod. 1024). As has been previously demonstrated[2–4]), V_Σ is practically independent from light transit time in the scintillators. Its amplitude depends only on the line-

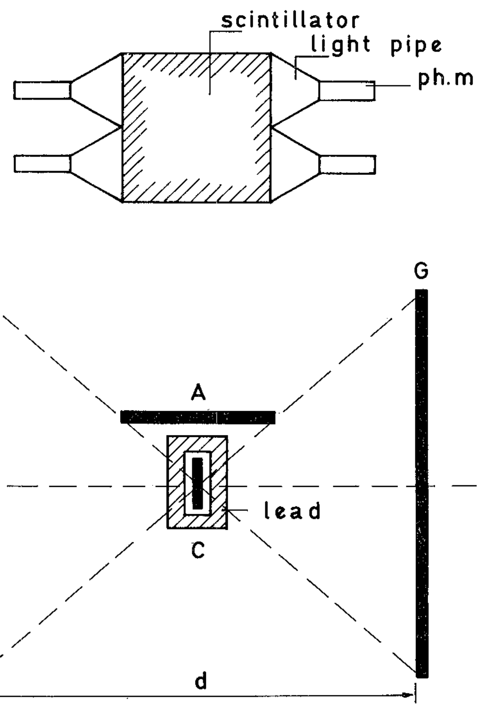

Fig. 1. The experimental set-up.

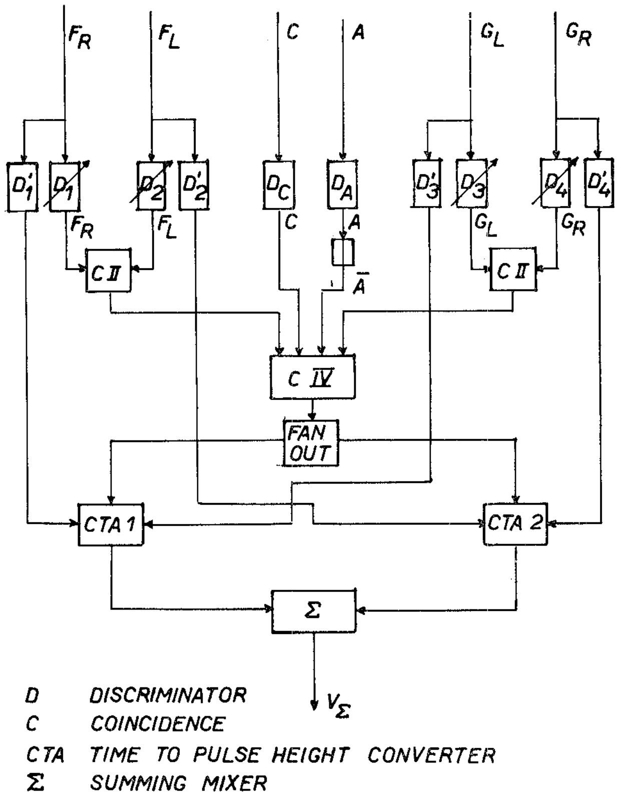

Fig. 2. The electronic block diagram.

of-flight of the ionizing particle. Events recorded by the multichannel are distributed into two gaussian shaped histograms. They are related to the number of cosmic rays flying from F to G and from G to F, these being the counters in the vertical plane. Distance between the centers of the two gaussians corresponds to a 2τ time interval. τ is the time-of-flight of a particle impinging perpendicularly on the counters.

Figs. 3, 4, 5 show distributions of events which have been obtained by varying the distance d between counters F and G. Width is about ± 0.7 ns when measured at half maximum of distribution.

Events from a collision between crossing beams give rise to a single distribution like that of fig. 4, centered at half distance between them (arrow in figs. 3, 4, 5).

If we choose a window $\pm \Delta t$ ns centered at the mid-point between the two peaks of the distribution of fig. 5 (dashed lines) we have a loss of good events and a rejection of cosmic rays. In table 1 are results for several values of Δt and for a distance $d = 1.5$ m between counters F and G. From this table we see that a 90% rejection of cosmic rays gives a loss $\lesssim 1\%$ of good events.

Some of the events which are in the previously defined window, are due to cosmic showers, which trigger contemporarily FG and C and simulate an event

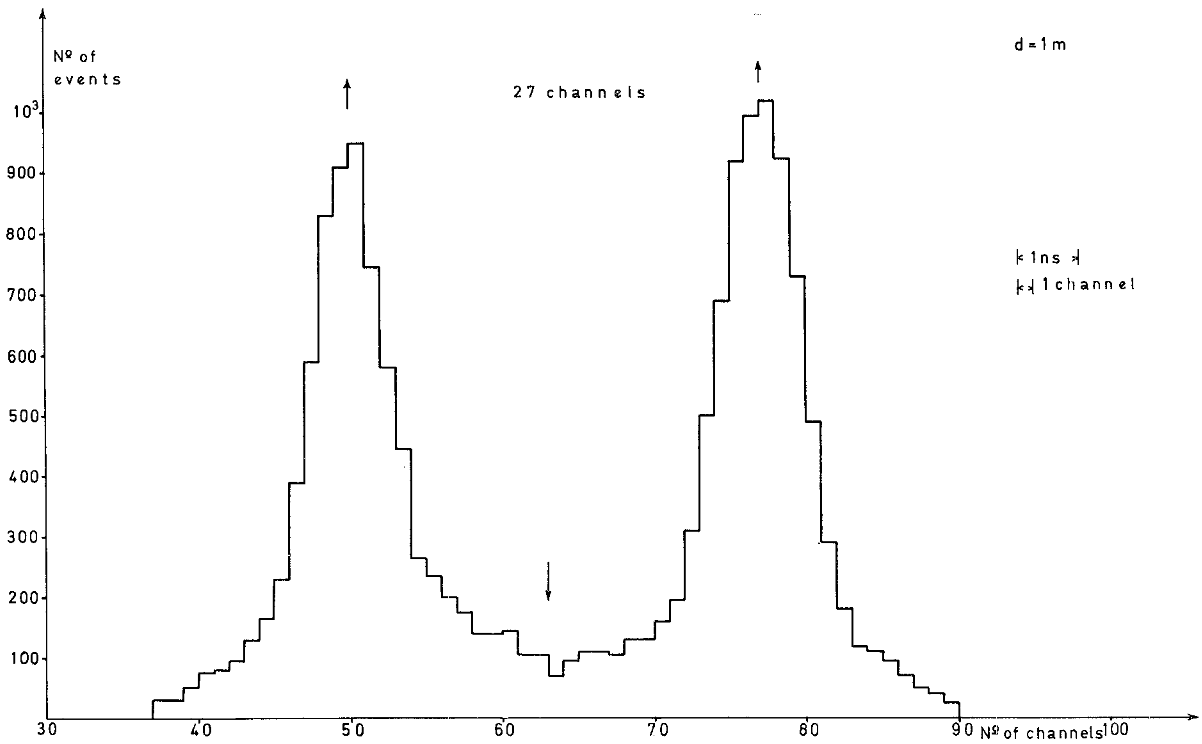

Fig. 3. Time of flight distribution of cosmic rays. Counter distance $d = 1$ m.

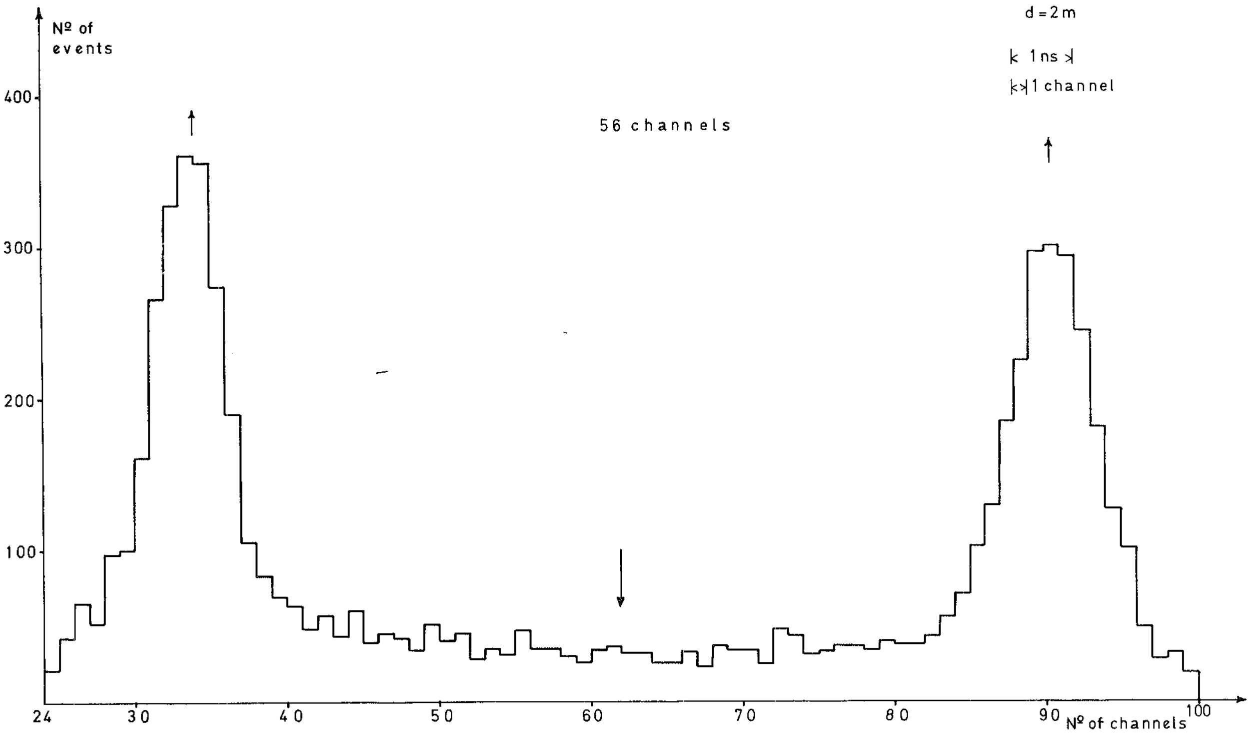

Fig. 4. Time of flight distribution of cosmic rays. Counter distance $d = 2$ m.

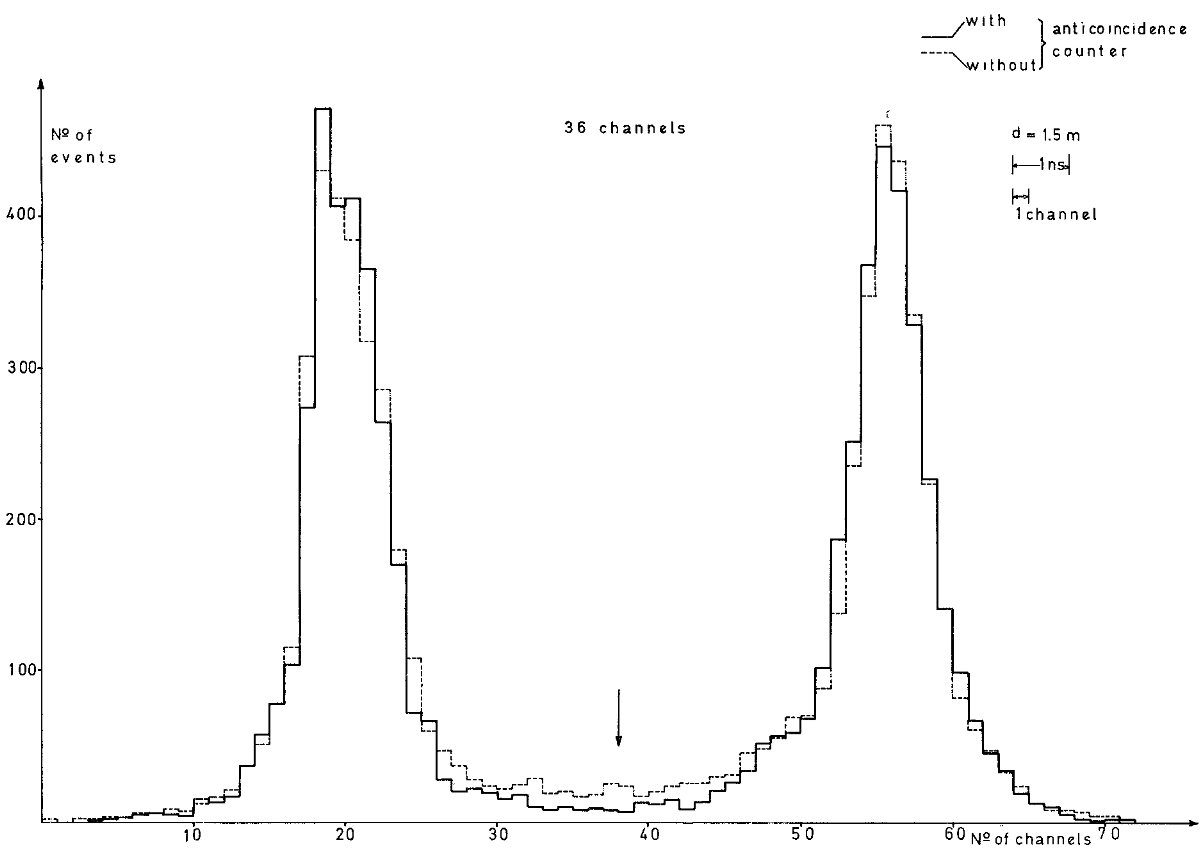

Fig. 5. Time of flight distribution of cosmic rays. Counter distance $d = 1.5$ m. Continuous line: when the anticoincidence counter A of fig. 1 is used; Dashed line: without the anticoincidence counter A.

TABLE 1

t(ns)	cosmic rays accepted with antic. (%)	cosmic rays accepted without antic. (%)	loss of good events (%)
± 2	2.7	5.1	5
± 3	6.6	9.75	1.07
± 4	13	16.8	0.29

$d = 1.5$ m (fig. 5).

coming from the interaction region. By using an anticoincidence counter A (fig. 1) the distribution of fig. 5 is modified as is shown (continuous line). From this we obtain that a loss $\lesssim 1\%$ of good events allows a 94% rejection of cosmic rays.

3. Conclusions

The time-of-flight method permits high resolution time measurements also when large scintillation counters are used. It permits directional measurements as well as a high rejection of cosmic rays events in experiments with colliding beams.

This method is particularly suitable for apparatus in which the interaction region lies between two symmetrical arrays[5]). It seems preferable to an anticoincidence method, which requires much larger scintillation counters external to the entire experimental apparatus.

When our experiment is performed at Adone the cosmic ray flux will be ≈ 20 counts/min in our solid angle, of which ≈ 120 counts/h will be in time coincidence with the crossing beams (frequency = 10 Mhz, assuming 10 ns total resolving time). By using the method described above, we expect a counting rate of only $\approx$ 7 counts/h due to cosmic rays in our apparatus[5]).

When spark chambers are used, analysis of the pictures further reduce the number of cosmic ray contaminations to less than 0.014 counts/h, by requiring that the tracks come from the interaction region.

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