EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

NP Internal Report 69-1

31 January, 1969

A "BACKCROSSING TYPE" PULSE DISCRIMINATOR

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A. INTRODUCTION

The time resolution in the detection of fast particles with long plastic scintillation counters is mainly limited by two effects:

1) "Slewing" in the pulse discriminator due to the finite rise time of the phototube pulse, high pulses triggering the discriminator earlier than low ones and

2) Travelling time of the photons from the scintillation centres to the photocathode of the multiplier.

With usual discriminators like the CERN types 6011 or 2615, the two effects are not separable. In addition, they are correlated to give time shifts in the same direction: particles traversing the far end of the scintillator (i.e. the end with no phototube) give the longest photon travelling time and the lowest photopulse. Cosmic ray measurements with 50cm x 80cm x 2cm plastic counters, 56 AVP multipliers and CERN type 6011 discriminators, give a combined time shift of 9 nsec/metre (see section C).

There are known ways to eliminate the two effects:

1) "Zerocrossing" discriminators (CERN type 2613) shape the phototube pulse before discrimination and succeed in getting slewing times which are much shorter than the pulse rise time. Circuits of this type have the disadvantage that they tend to

multiple pulse, i.e. input pulses of non-ideal shape give two or more output pulses.

2) By equipping both ends of a long scintillation counter with phototubes and forming a suitable sum of the two pulses, one can eliminate the photon travelling time. Resolutions below 1 nsec/metre have been reached using this method.

The following paper describes a relatively simple method to achieve resolution times of about 6 nsec/metre using scintillation counters with only one phototube. It is based on the correlation between travelling time and pulse height as mentioned before. Fig. 1 explains the principle:

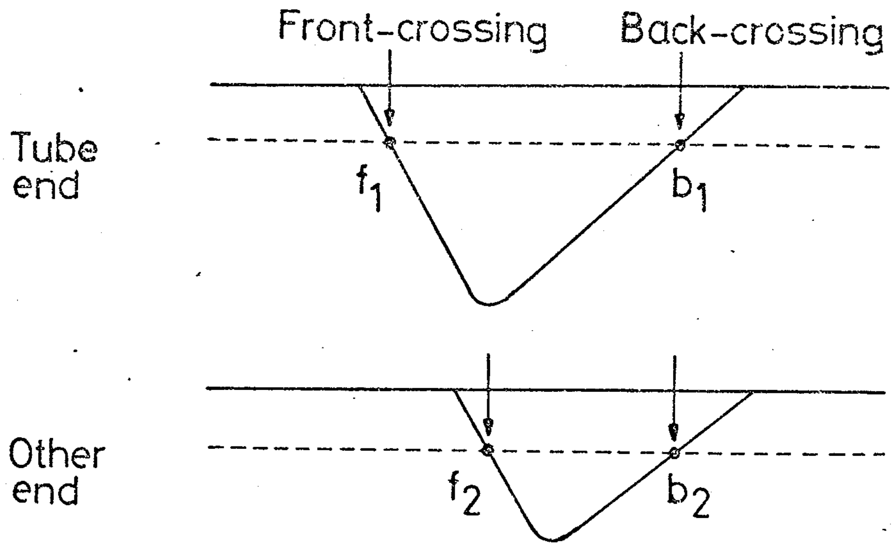


Fig.1

A fast particle traversing the counter near the tube gives rise to a photopulse P_1 crossing the discrimination level at times f_1 and b_1. A particle traversing at the same time the far end of the counter gives P_2 with f_2 and b_2. If now all detected particles scintillate like singly charged relativistic particles, the range of times b_1, b_2... can be made much smaller than the usual range f_1, f_2... In section B we describe a circuit which can realise this method, and in section C we report the result of some measurements.

B. CIRCUIT

Principle: A first discriminator sets a threshold for the front edge of the PM pulse. The normalised discriminator output pulse (fig. 2a) is mixed with the differentiated PM pulse (b) as shown in (c). An adjustable differentiation time constant is necessary to set the fall times of the PM pulses for minimum time slewing $b_1 - b_2$ (see fig. 1). After mixing, a second discrimination stage gives an output pulse when pulse c exceeds its threshold. The circuit, as shown in fig. 3 contains differentiation, mixing and second discrimination. For the first discrimination, a standard CERN type 6011 is used.

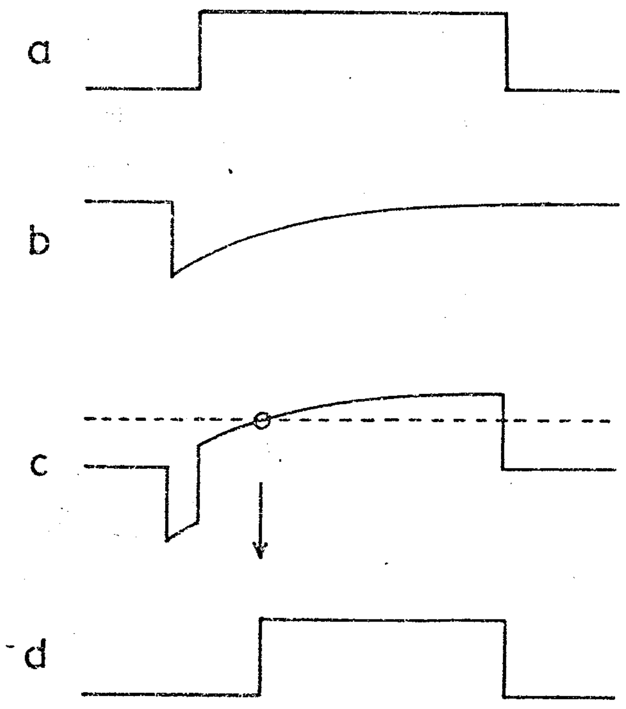


Fig. 2

Detailed Description: (see fig. 3) A differentiating

BACK-CROSSER

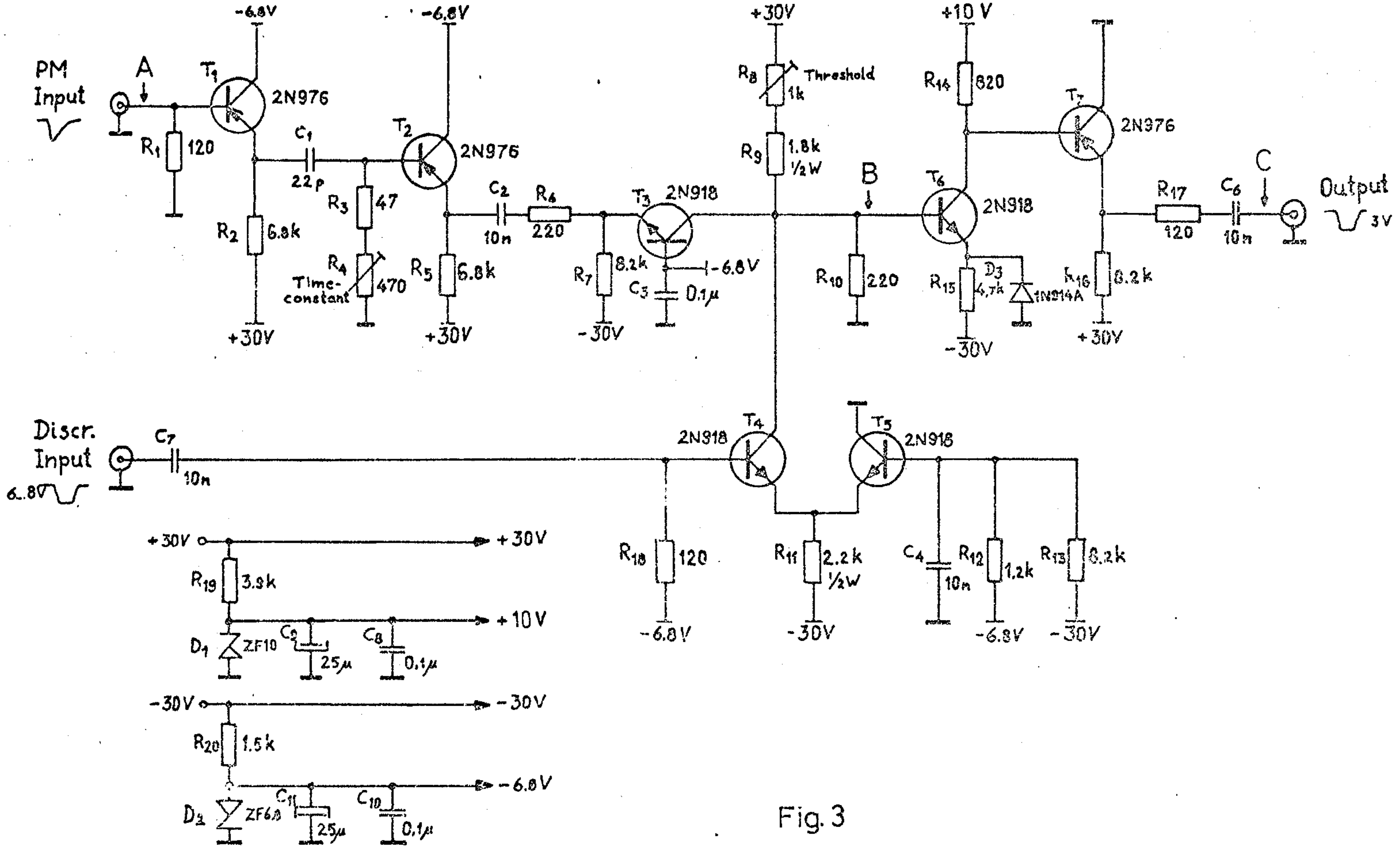


Fig. 3

circuit with adjustable time constant (C_1, R_3 and R_4) is used to shape the PM pulse. Because of the fast pulse rise, the rise time is not noticeably affected, but the long fall time is shortened according to the setting of R_4. The differentiating circuit is matched to 125 Ω input impedance by means of an emitter follower (T_1). The next stage (T_2) is also an emitter follower with small load on the differentiation circuit.

The mixer consists of two current generators. One of them (T_3) gives a current proportional to the PM pulse amplitude plus the bias current through R_7. The other one is a differential stage (T_4 and T_5) acting as a current switch. When no input signal is present, T_4 is conducting. The two currents and a bias current through R_8 and R_9 are added in R_{10}. The threshold potentiometer (R_8) is adjusted to give a bias current less than the sum of the currents through T_3 and T_4. Hence, the current difference passes R_{10} giving a negative voltage at point B. The output stage (T_6 and T_7) forms a simple discriminator with a threshold of about 0 V.

When a PM pulse arrives, the voltage at point B becomes more negative. The leading edge of the discriminator pulse to T_4 is adjusted to come shortly after the peak of the PM pulse (see fig. 2). The discriminator pulse switches T_4 off, making the voltage at point B less negative. After a certain time, the PM pulse current through T_3 has dropped enough to make the point B voltage exceed the threshold of the output stage. The output pulse starts at this time and lasts until the discriminator input pulse ends. The length of the output pulse depends on the external discriminator and the shaped PM pulse lengths.

C. MEASUREMENTS

The unit described in section B was tested with various counters. We report here the results obtained using a scintillator 80cm long, 50cm wide and 2cm thick. It was equipped with a 56 AVP photomultiplier and was tested with cosmic rays in coincidence with two smaller counters (20 x 20 x 2cm) as shown in fig. 4. Counters 2 and 3 could be moved to different positions along 1. A layer of 5cm lead was put between 1 and 3 to look only at pulses from the hard component of the cosmic radiation. The properties of the testcounter were studied by displaying its PM pulses on an oscilloscope triggered by coincidences between counters 2 and 3. Pulses from the tube end of the counter were found, on average, to be 2.3 times higher than those from the far end. The time of flight effect (defined as the shift of the pulse maximum relative to the scope trigger) was about 4.5 nsec/60cm. This increased to 5.2 nsec/60cm when measuring triple coincidences with a CERN type 6011 discriminator after the PM tube of

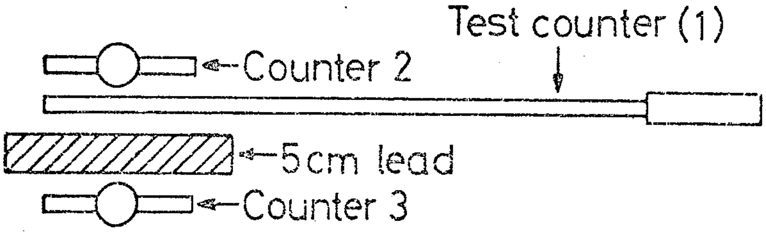


Fig.4

counter 1. Figure 5a shows the result of two of these triple coincidence measurements. A CERN type 6225 coincidence unit was used, with type 2615 pulse shapers in front (set to 5 nsec pulse width).

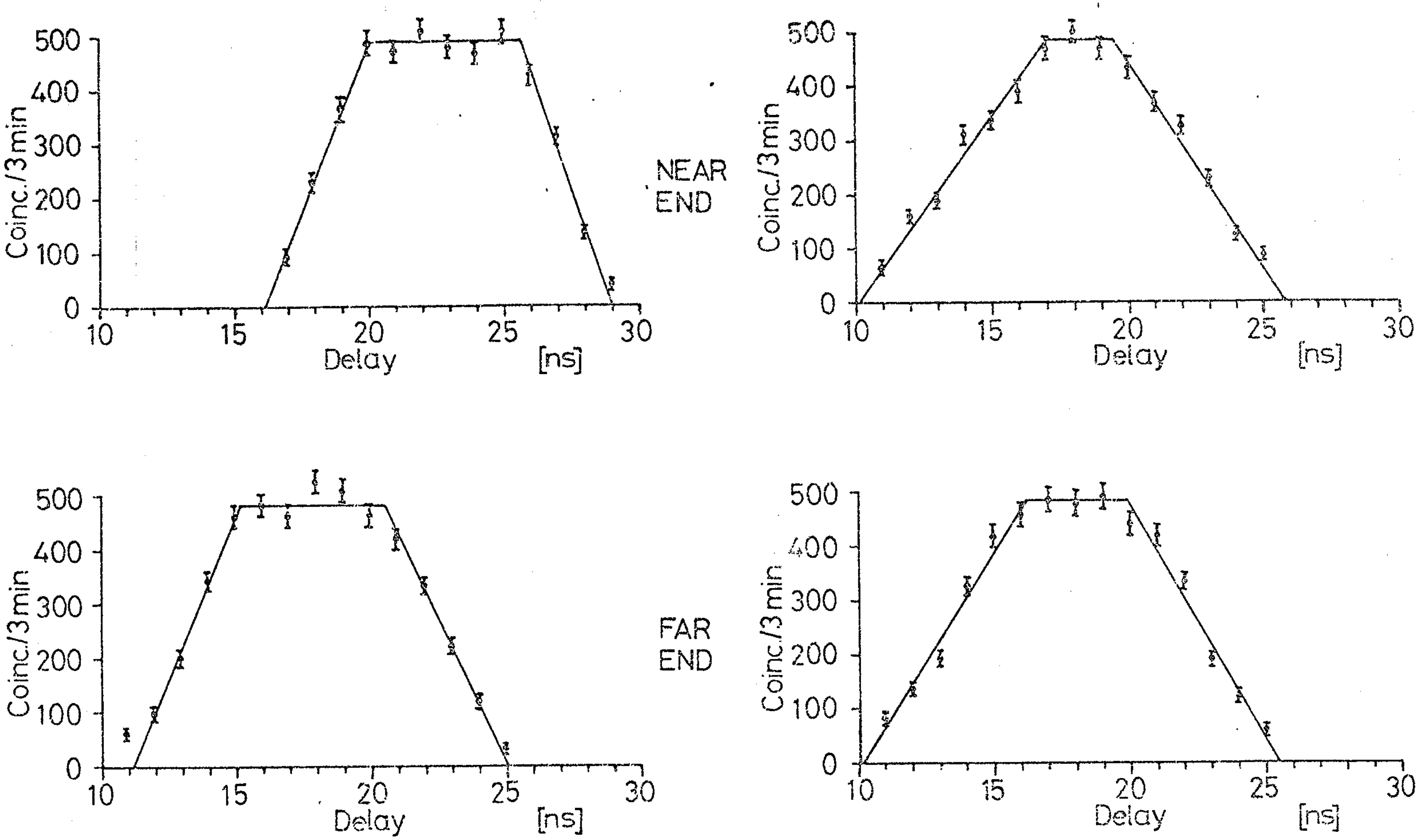
Figure 5b shows the result of two measurements in the same configurations as 5a, but with the 6011 discriminator replaced by the combination 6011 plus "backcrosser". The threshold of the 6011 unit was unchanged. There are two adjustable parameters for optimizing the time resolution:

1) The relative delay between PM input and discriminator input of the "backcrosser", and

2) The differentiation time constant mentioned before.

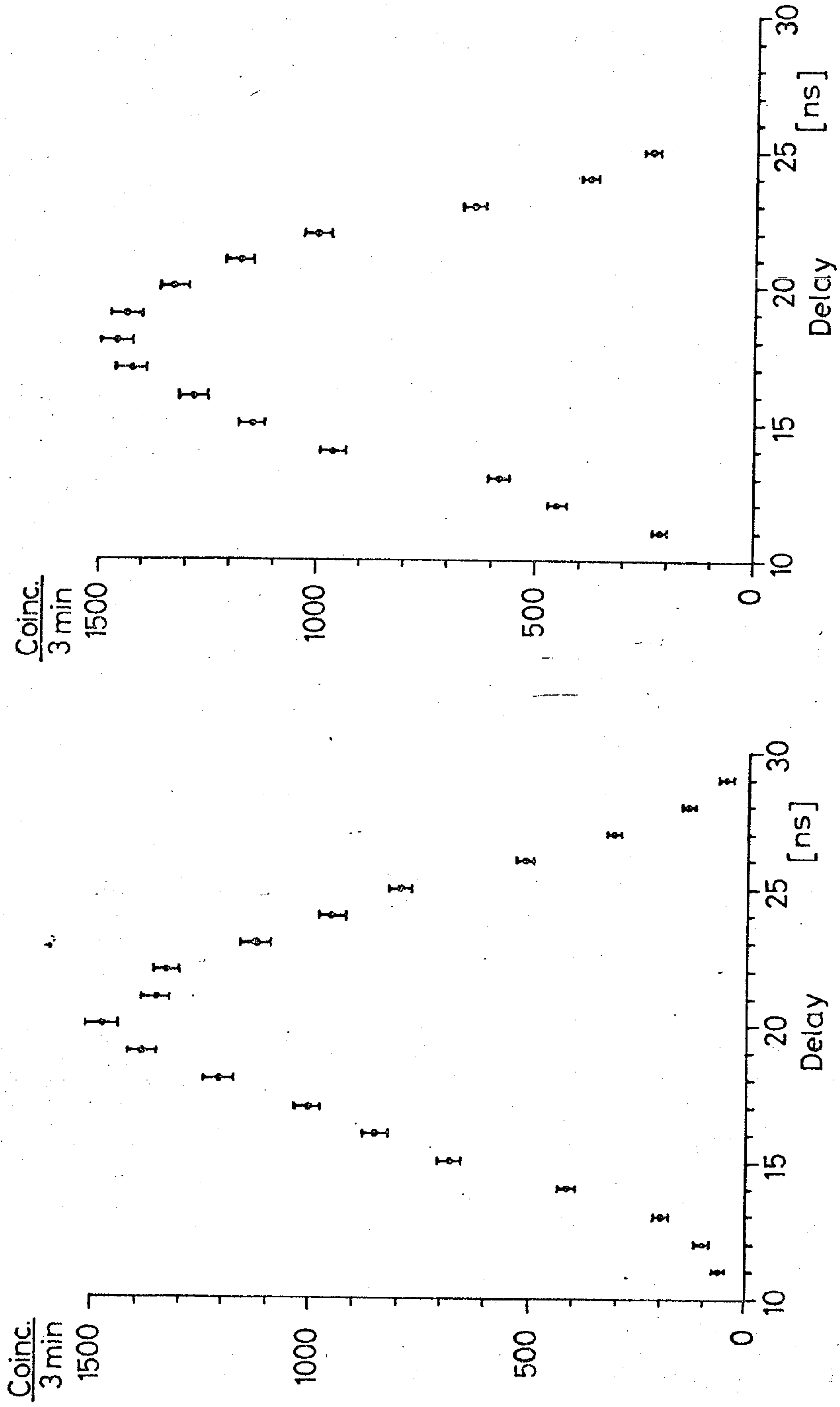
Within a certain range, about 5 nsec in length, the relative delay is not critical. Furthermore it has to be adjusted only once per unit, and is independent of the counter with which it is used. The choice of the differentiation time constant may depend on the individual counter. It was set to give zero time shift in the coincidence measurements of fig. 5b.

Figure 6 shows the addition of the curves in figure 5 plus, in each case, a third curve which was taken in the centre of the testcounter. This rough integration over the whole length of the counter gives 7.5 nsec time resolution for the "frontcrossing" and 5.5 nsec for the backcrossing. In another configuration, i.e. measuring twofold coincidences between two long counters, an improvement in resolution time from 12 nsec to 8 nsec was obtained.



a) Front-crossing b) Back-crossing

Fig. 5



a) Front-crossing

b) Back-crossing

Fig. 6

We would like to thank Messrs. J. Chollet, J-M. Gaillard, M.R. Jane, T.J. Ratcliffe, J-P. Repellin and B. Wolff for many helpful discussions.