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A LOW-LEVEL ULTRA-FAST DIFFERENTIAL DISCRIMINATOR

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ABSTRACT

This paper describes a NIM module with eight low-level, ultra-fast differential discriminator channels.

The module is designed to increase the operating intensity of photomultipliers to 5×10^7 pulses per second. It allows the use of a very long transmission cable (from 200 to 300 m) between the photomultiplier and the module input.

This type of differential discrimination provides:

- high noise immunity;
- a triggering threshold from 1 mV;
- a double-pulse resolution of 4 ns (250 MHz).

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CONTENTS

1. INTRODUCTION

The fastest methods of detection in particle physics experiments usually make use of photomultipliers (PMs), which convert the light pulses engendered by the passage of the particles (Čerenkov effect, scintillation, transition radiation or synchrotron radiation) into electric signals.

The output signal of the PM must then be taken via long cables to the electronic detection system.

What is described here is an eight-channel discrimination module providing an improvement of one order of magnitude in the rate acceptable by the PMs. It facilitates the reception of signals after long-distance transmission (100 to 300 m) whilst maintaining the time resolution.

2. DRAWBACKS OF THE CONVENTIONAL AMPLITUDE-THRESHOLD DETECTION SYSTEM

a) Level discriminators are used to detect pulses from the PMs. The lowest threshold commonly used is 30 mV in order to maintain good noise immunity. With the attenuation in the cable taken into account, a minimum amplitude of 200 mV at 50 Ω is needed at the PM output in order to maintain good time resolution. As the average anode current is limited to 0.2 mA, the counting rate cannot be higher than 5×10^6.

b) The leading edge of the PM output signals is fast, but the decay time constant is slow. This effect is aggravated by the passage through the transmission cables. There are thus broad-based pulses at the discriminator inputs. The detection threshold is generally adjusted to $1/5$ of the amplitude and the double-pulse resolution cannot be better than 30 to 50 ns.

3. AIMS

The aim in view is to improve the performance of the existing systems with the minimum number of modifications. It was therefore decided to develop a highly sensitive differential discriminator that would replace the old ones.

The very low threshold (1 mV) makes it possible to operate with smaller pulses at the PM outputs and hence to raise the maximum counting rate.

Differential discrimination was chosen because it eliminates the drawbacks of the pile-up effect and improves the double-pulse resolution.

4. DIFFERENTIAL DISCRIMINATION

This type of discrimination has already been successfully used[1,2].

The discriminator signals the presence of a pulse when the input signal variation exceeds an adjustable threshold within a given time.

$$\frac{du}{dt} > \text{threshold} ,$$

where dt = 2 ns is fixed (can be easily changed) and du is adjustable from -1 to -100 mV.

Advantages of differential discrimination

a) Insensitivity to base-line shifting, zero drift and continuous polarization.

b) Insensitivity to pile-up effects (see Section 8).

c) Better noise immunity.

With a threshold adjusted to 10 mV, 16,000 V at 50 Hz or 800 mV at 1 MHz are needed to trigger the circuit.

5. DESCRIPTION OF THE MODULE

As this module (Fig. 1) is intended to replace the level discriminators so far used, it has the same shape. There are therefore eight channels grouped together in a NIM module 1 unit wide.

Each channel comprises 1 input, 2 outputs and 1 complementary output at NIM levels. There are separate adjustments of the input threshold and of the output pulse width for each channel.

6. PERFORMANCE AND CHARACTERISTICS

6.1 Input characteristics

Lemo 00 50 Ω connectors on the front panel;
maximum input signal amplitude: 500 mV;
differential threshold adjustable by potentiometer on the front panel

$$\frac{du}{dt} = \frac{-1 \text{ to } -100 \text{ mV}}{2 \text{ ns}} .$$

The threshold voltage may be measured at a test terminal on the front panel; the read-out is 10 times the threshold voltage.

The 2 ns delay selected for the test module may easily be changed if necessary.

6.2 Output characteristics

Lemo 00 50 Ω connectors on the front panel, NIM levels;
pulse width adjustable from 3 to 20 ns by a potentiometer on the front panel.

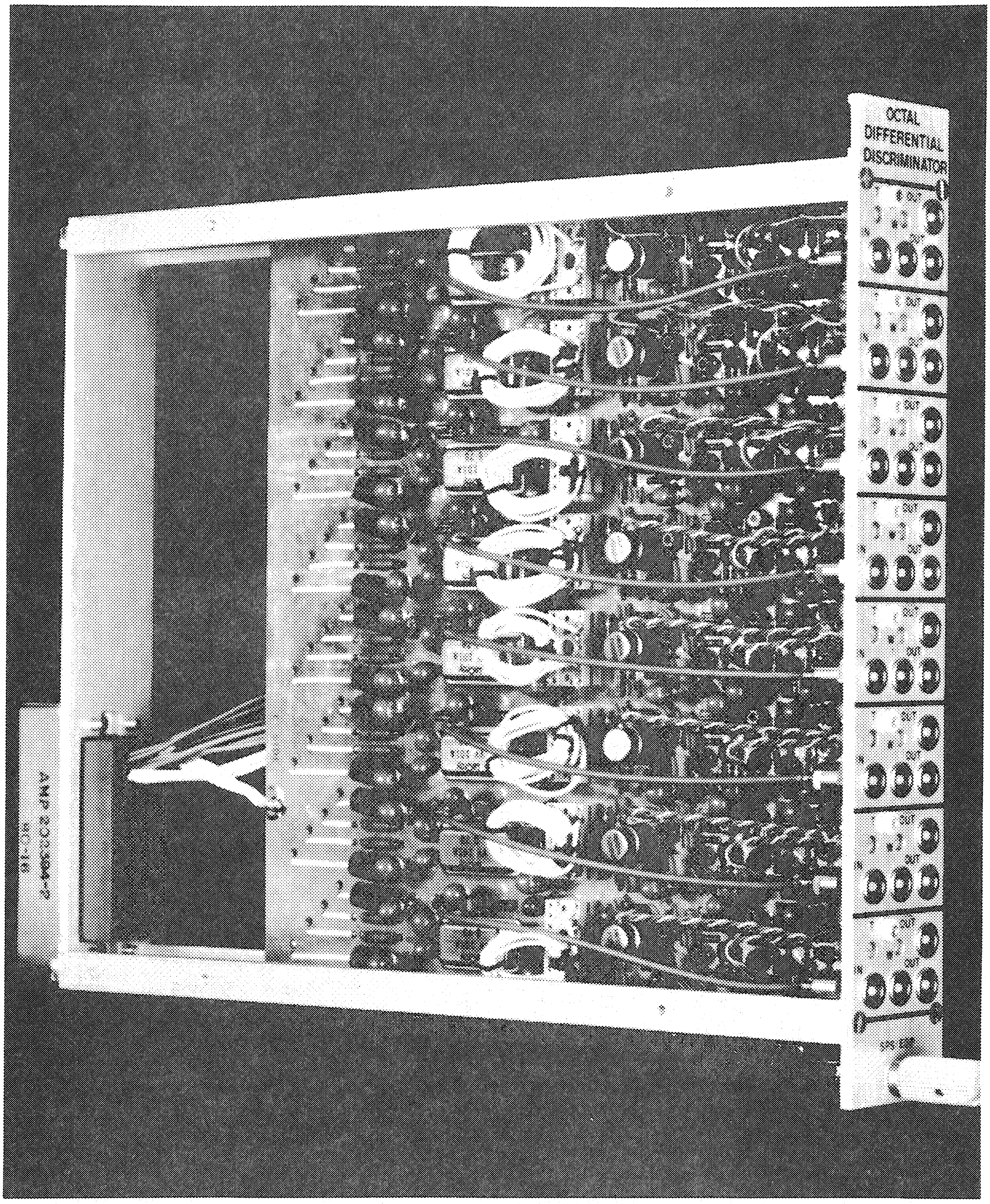

Fig. 1 Photograph of the module

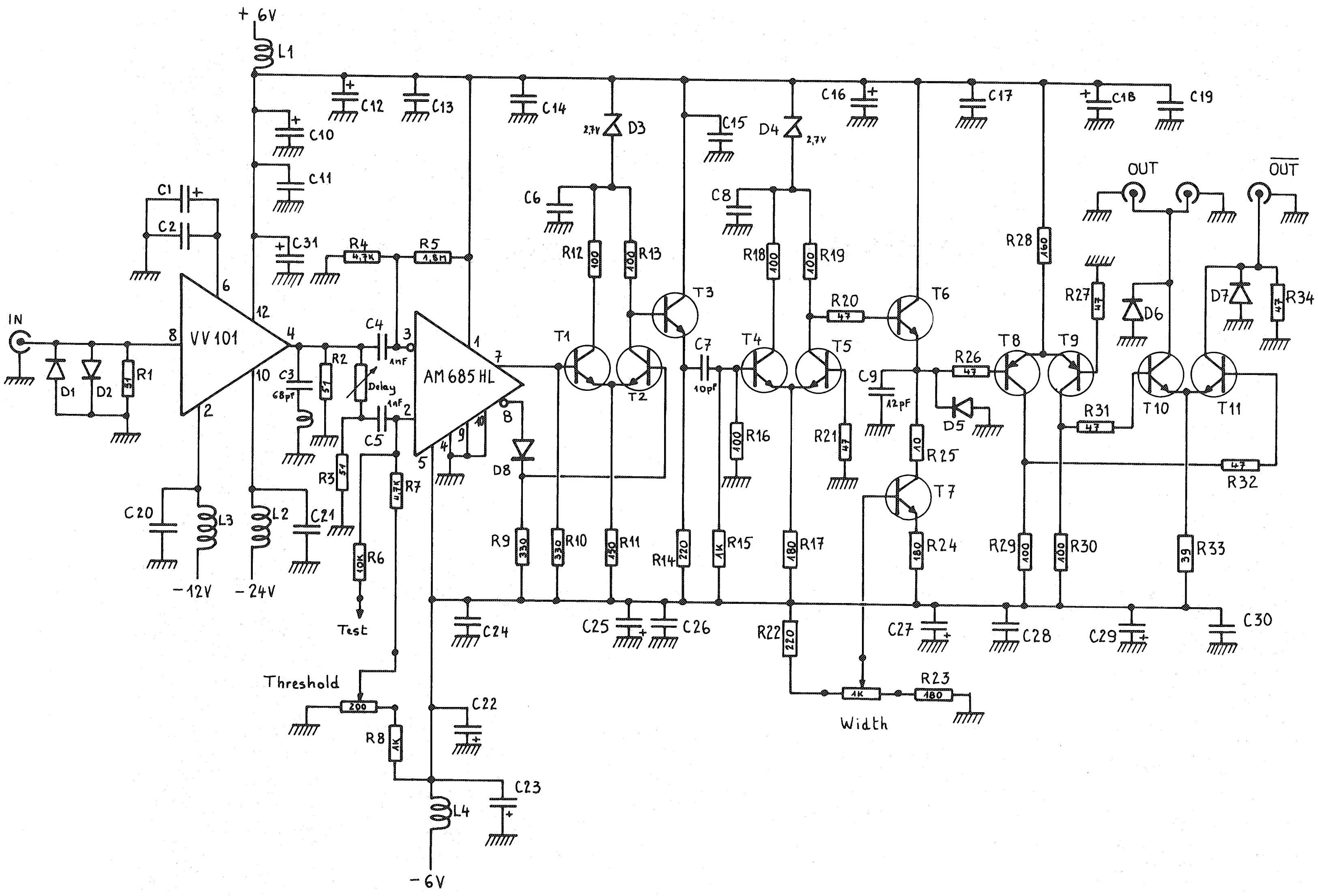

Fig. 2 Circuit diagram of one of the eight channels of the diffential discriminator

6.3 General

Maximum frequency: 250 MHz,

double-pulse resolution: 4 ns,

time slewing ≤ 0.5 ns for amplitudes 2 to 20 times higher than the threshold,

transit time: 9.6 ns,

power consumption: -6 V 2 A; +6 V 1.2 to 1.6 A;
-12 V 0.16 to 2 A; -24 V 0.06 A.

7. DESCRIPTION OF THE CIRCUIT (see Fig. 2)

The input signals pass through an amplifier (VV 101) with a gain of 10. They are then discriminated by the differential comparator AM 685, the additional output signals of which are shaped and amplified by T_1T_2. The leading edge is then differentiated by the circuit C7 R16 and the signal obtained is discriminated by T_4T_5.

The width of the output pulse is adjusted by the current generator T7 by discharging the capacitor C9, previously charged by a pulse of constant width and amplitude.

The delta signal produced by the current generator is shaped by T_8T_9 and $T_{10}T_{11}$ before being sent to the outputs.

8. RESULTS

Reference will be made in all these tests to the "discriminator threshold" related to the input. It will always be the threshold of comparator AM 685, divided by 10 to allow direct comparison with the input signal.

8.1 Test with fast pulses at the input

Figure 3 shows the discrimination between two pulses separated by less than 4 ns, with the discriminator threshold at -5 mV.

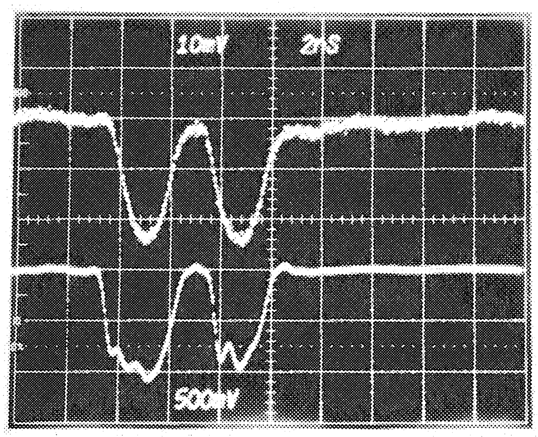

Fig. 3

Input
(10 mV, 2 ns/div.)

Output
(500 mV, 2 ns/div.)

Figure 4 shows the frequency response with a series of pulses at 250 MHz, with the discriminator threshold at -5 mV.

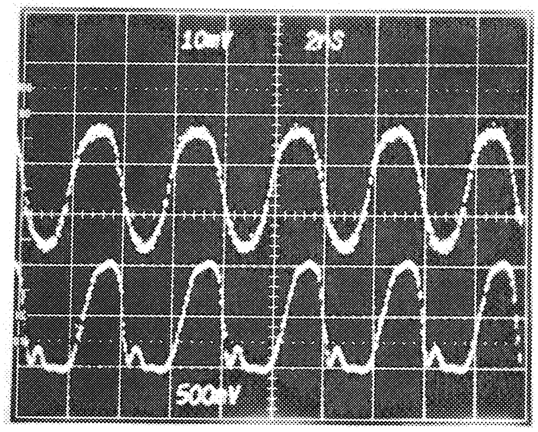

Fig. 4

Input
(10 mV, 2 ns/div.)

Output
(500 mV, 2 ns/div.)

8.2 Test with PM pulses (simulated)

In this test, the PM pulses were simulated by sending short pulses through 200 m of RG 213 cable. In Fig. 5, the two pulses were separated by 5 ns. The discriminator threshold was set at -5 mV.

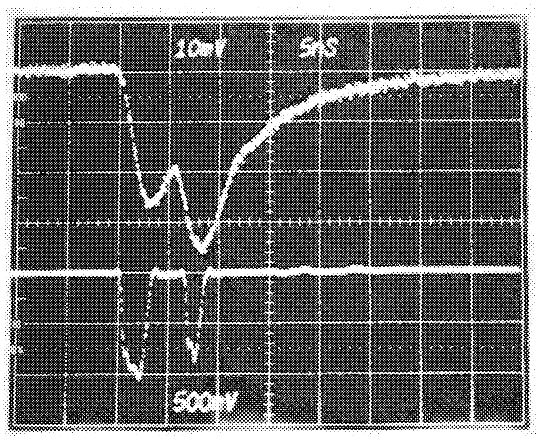

Fig. 5

Input
(10 mV, 5 ns/div.)

Output
(500 mV, 5 ns/div.)

In Fig. 6, the series of pulses was sent at 200 MHz. In the input signal, there is a zero shift of 65 mV.

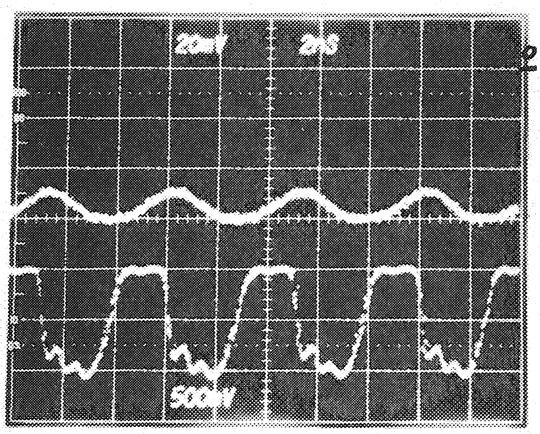

Fig. 6

Input
(20 mV, 2ns/div.

Output
(500 mV, 2 ns/div.)

8.3 <u>Demonstration of the sensitivity and noise immunity of the discriminator</u>

In Fig. 7, the discriminator threshold is set to -1 mV. The discriminator flips with a change of the order of 0.05 pC above the threshold.

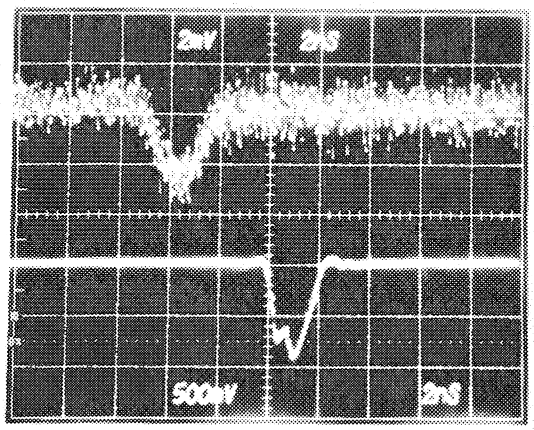

Fig. 7

Input
(2 mV, 2 ns/div.)

Output
(500 mV, 2 ns/div.)

Figure 8 shows two types of simulated PM pulses drowned in 50 Hz noise. The discriminator threshold was set at -1 mV. The oscilloscope is triggered by an outside signal, and it is clear that, although the input signal is greatly affected by the noise, there is no "jitter" on the output signal in either Fig. 8a or 8b.

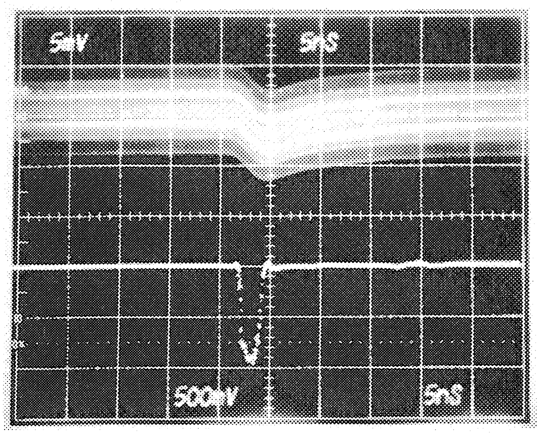

Fig. 8a

Input
(5 mV, 5 ns/div.)

Output
(500 mV, 5 ns/div.)

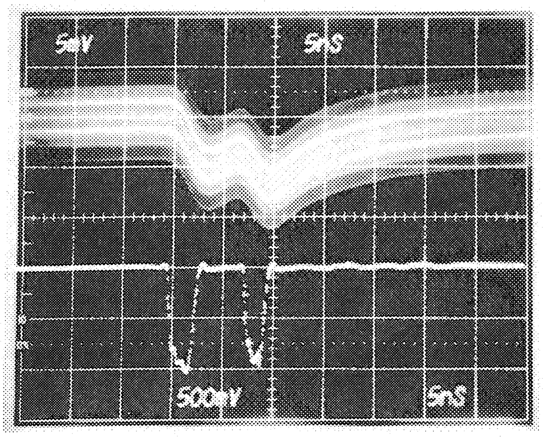

Fig. 8b

Input
(5 mV, 5 ns/div.)

Output
(500 mV, 5 ns/div.)

8.4 Error in the measurement of the time of flight of the second of two pulses in relation to the time between them

As regards the measuring conditions, the pulses were identical to those of Fig. 3. The amplitude was 25 mV, the threshold set at -5 mV, the differentiation delay was 2 ns. Results in the following table are in ns.

Time between 2 pulses	Error
10	-0.1
9	0
8	+0.1
7	+0.2
6	+0.1
5	+0.4
4	+0.4

9. CONCLUSIONS

This module makes it possible to use the PMs (even in existing installations) with an intensity ten times higher than with conventional amplitude-threshold discriminators, whilst maintaining good noise immunity and a satisfactory time resolution.

It can very easily be adapted to detect slower signals which exhibit pile-up effects (very long distance transmission, wire chambers, semiconductor detectors, etc.), simply by changing the plug-in delay line to match it to the leading edge.

We should like to thank our colleagues in the EA Groups who, through their advice and support, helped build this module.

REFERENCES

1) D. Brahy and E. Rossa, High-rate photomultiplier base and precise timing calibration, CERN-SPS/EA/78-11 (1978).

2) D. Brahy and E. Rossa, Comptage d'un faisceau avec une discrimination différentielle "Trigger Receiver", CERN/SPS/81-2 (EBP).