COMITATO NAZIONALE PER L'ENERGIA NUCLEARE
Laboratori Nazionali di Frascati

LNF-62/38

A.C. Odian and G. Ubaldini:
FAST FOURFOLD COINCIDENCE CIRCUIT.

Nota interna: n° 137
18 Maggio 1962

Servizio Documentazione
dei Laboratori Nazionali di Frascati del CNEN
Casella Postale 70 - Frascati (Roma)

Laboratori Nazionali di Frascati del C.N.E.N.
Servizio Documentazione

LNF-62/38

Nota interna: n° 137
18 Maggio 1962

A.C. Odian and G. Ubaldini:
FAST FOURFOLD COINCIDENCE CIRCUIT

The fourfold coincidence circuit used in the μ pair experiment was a first approximation to an ideal coincidence circuit. The important properties of such an ideal circuit are the following:

1) Short resolving time.
2) 100% Efficiency.
3) Convertible into a threefold, twofold or single circuit.
4) Short dead time at the inputs and the output.
5) outputs of both polarities, at least one being capable of driving another similar circuit.
6) Stability with respect to voltage drift of the power supplies.
7) Stable and Rugged.
8) A reasonable threshold of photomultipliers

A coincidence circuit will have a short and constant resolving time only if the inputs are formed in amplitude and in duration. There are many different types of limiters used for this purpose. We have used a diode limiter in conjunction with a shorted stub to form the input pulse. Diodes were used instead of vacuum tubes or transistors because they are faster. They present some problems of impedance matching but these can be overcome. The inputs are all D.C. coupled to avoid level shifts at high input rates. The coincidence circuit consists of a diode Rossi circuit followed by a tunnel diode discriminator to separate triples from fourfolds with a short dead time.

In the circuit used, two fourfold coincidences and one double were mounted on the same chassis (See fig. 1). Outputs were available for counting the fourfolds. The inputs of the double were internally connected to the outputs of the fourfolds thus forming an eightfold from the two fourfolds. The inputs used had an impedance of 125 ohm and outputs 200 ohm. This has been changed in subseguent circuits to 125 ohm.

The limiter

The input pulses are limited to 3 V when they cut off 30 ma in an impedance of 100 ohm. The 100 ohm consists of the 200 ohm shorting stub in parallel with the 200 ohm input resistance of the coincidence circuit (See fig. 2). Two Q6/100's in parallel were used to conduct the 30 ma. A third cut off Q6/100 helped to clamp the input for large pulses to serve as a safety for the other two. Probably it would be better to substitute FD100 for the conducting diodes and add about 100 ohm in series with the safety Q6/100 to terminate the input for large pulses. The input is vaguely terminated because the 100 ohm of the parallel combination plus the foreward resistance of the conducting diode approximate 125 ohm. In any case it is advisable to terminate the cable at the photomultiplier.

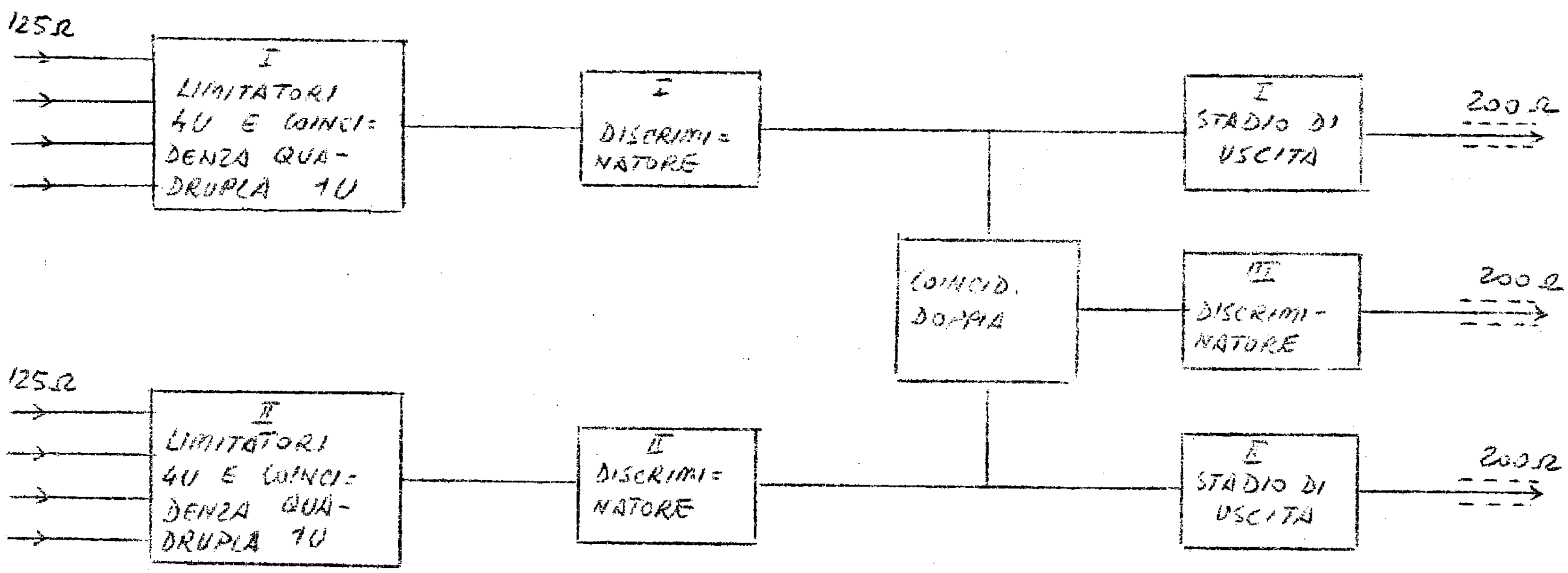

125Ω
I
LIMITATORI
4U E COINCI=
DENZA QUA-
DRUPLA 1U
I
DISCRIMI=
NATORE
I
STADIO DI
USCITA
200Ω
COINCID.
DOPPIA
III
DISCRIMI-
NATORE
200Ω
125Ω
II
LIMITATORI
4U E COINCI=
DENZA QUA-
DRUPLA 1U
II
DISCRIMI=
NATORE
II
STADIO DI
USCITA
200Ω

FIG. 1

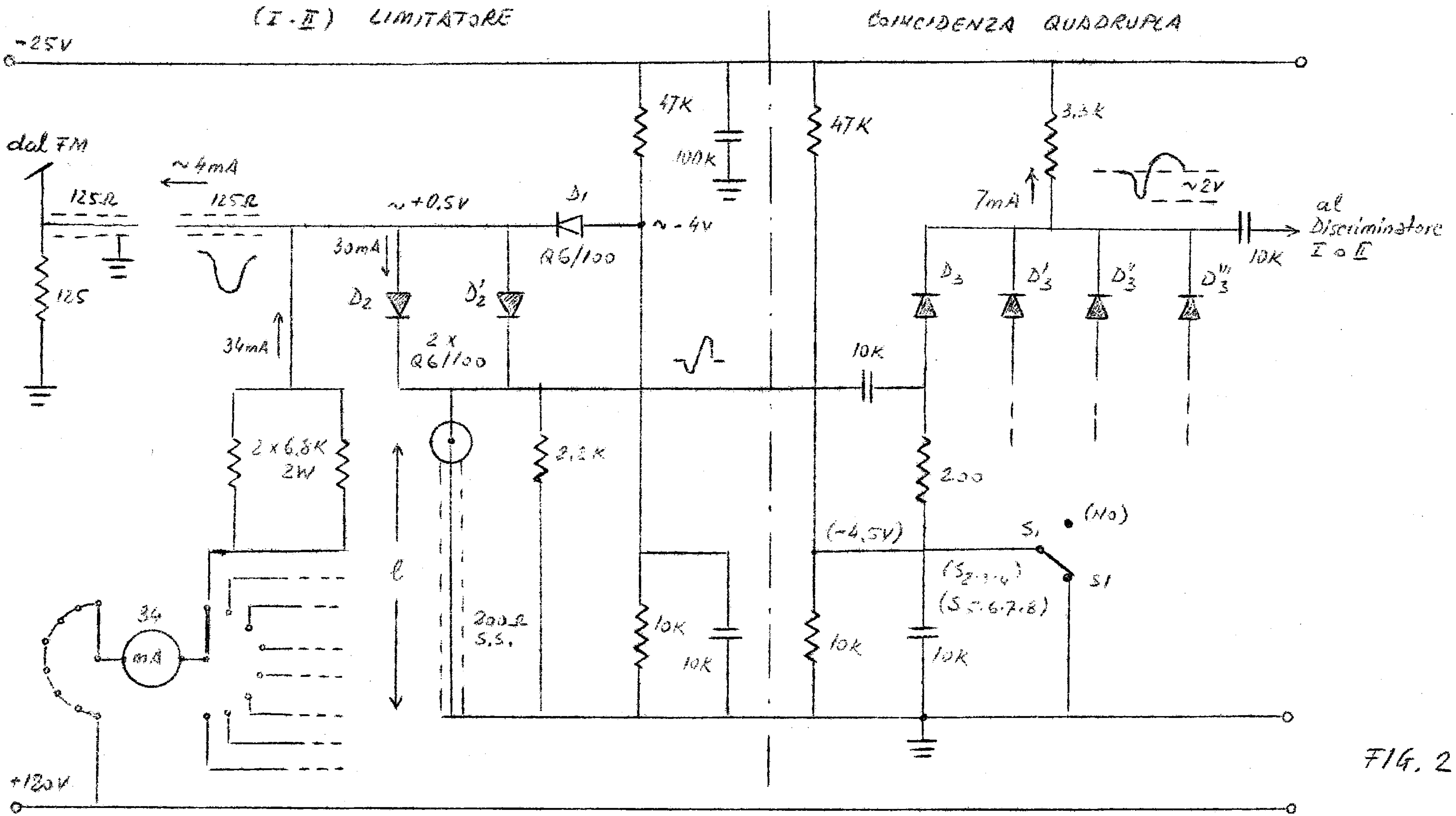

(I - II) LIMITATORE
COINCIDENZA QUADRUPLA
-25V
+120V
dal FM
125Ω
125
~4mA
34mA
30mA
~+0,5V
D1
Q6/100
~-4V
D2
D'2
2 X
Q6/100
47K
100K
2x6,8K
2W
2,2K
200Ω
S.S.
l
34
mA
10K
7mA
3,3k
~2V
al
Discriminatore
I o II
D3
D'3
D''3
200
(-4,5V)
S1
(No)
(S2·3·4)
(S5·6·7·8)

FIG. 2

The Rossi Coincidence

Consider the diode Rossi double coincidence shown in fig. 3.

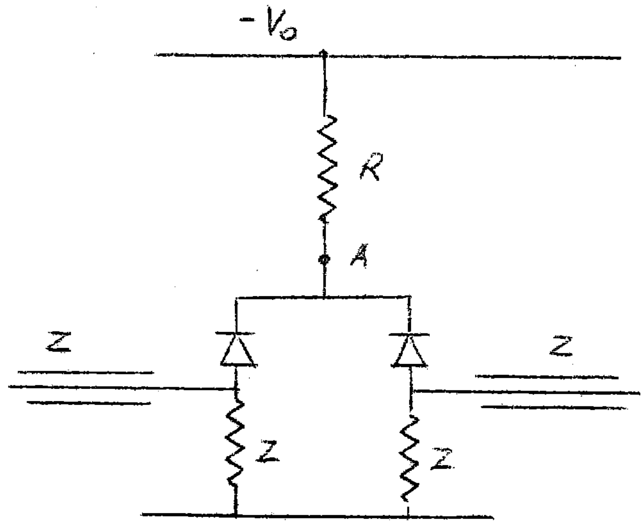


FIG. 3

If $R \gg Z$ and $V_o \gg$ the drop across the diodes, the voltage at the point A is negligibile with respect to V_o. Thus the resistor R carries a current $I \approx \frac{V_o}{R}$. This current is divided equally between the two diodes each one conducting $\frac{I}{2}$. If there are two input pulses of different amplitudes the pulse at A is equal to the smaller of the two. If they are equal the pulse at A to the inputs in the approximation $V_{in} \ll V_o$.

Instead, if there is only one input, the pulse at A is $V_A = \frac{IZ}{4} + \frac{I}{2} R_f$. (Remember that the input cable is in parallel with the resistor Z). Where R_f is the average resistance of the diode when the current changes from $\frac{I}{2}$ to I.

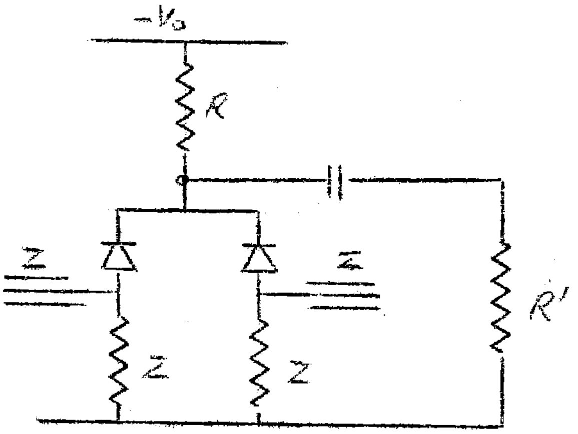
The ratio of doubles to singles is thus:

$$K = \frac{V_{in}}{\frac{IZ}{4} + \frac{I}{2} R_f}$$

We see that this ratio is large for small I and small Z. However, R_f increases for small I. Therefore it is not worth while to diminish the current below 1 ma per diode.

Here we have not considered the output circuit (See fig. 4). If the output circuit presents an impedance R' at the point A, the maximum output is $V_4 = \frac{R'}{R+R'} V_0$ for a double. For a single it is

$$V_s = \frac{I}{2}\left[\frac{(\frac{Z}{2}+R_f)R'}{\frac{Z}{2}+R_f+R'}\right]$$



Thus

$$k = \frac{2\left[\frac{Z}{2}+R_f+R'\right]}{\frac{Z}{2}+R_f}$$

FIG. 4

We see that the ratio improves by increasing R'. R' is determined by the discriminator used. The discriminator used (see fig. 5) had a IN2941 tunnel diode with 220 ohm in series. Thus R' ≈ Z' in this case. With 220 ohm 's in series with the 5 ma tunnel diode, the threshold of the discriminator is about 1.16 V = $220 \times 5 \times 10^{-3} + 0.06$. The reason that the threshold of the discriminator was chosen about one half of the limited input pulse is to fix the resolving time 2τ about equal to the duration of the formed input pulses. The current I in the coincidence used was 7 ma to assure a margin of safety for triggering the tunnel diode. The point A of the coincidence had a pulse of $\approx 2V = 7 \times 10^{-3} \times 222 + 0.5$ for a proper fourfold coincidence. Given that the input pulses are 3 V high, guarantees that the 7 ma are switched into the tunnel diode. Since a 5 ma tunnel diode triggers badly when loaded by the base of a transistor, the emitter of the 2N769 was biased at 0,2 volt to the threshold of conduction by a con-

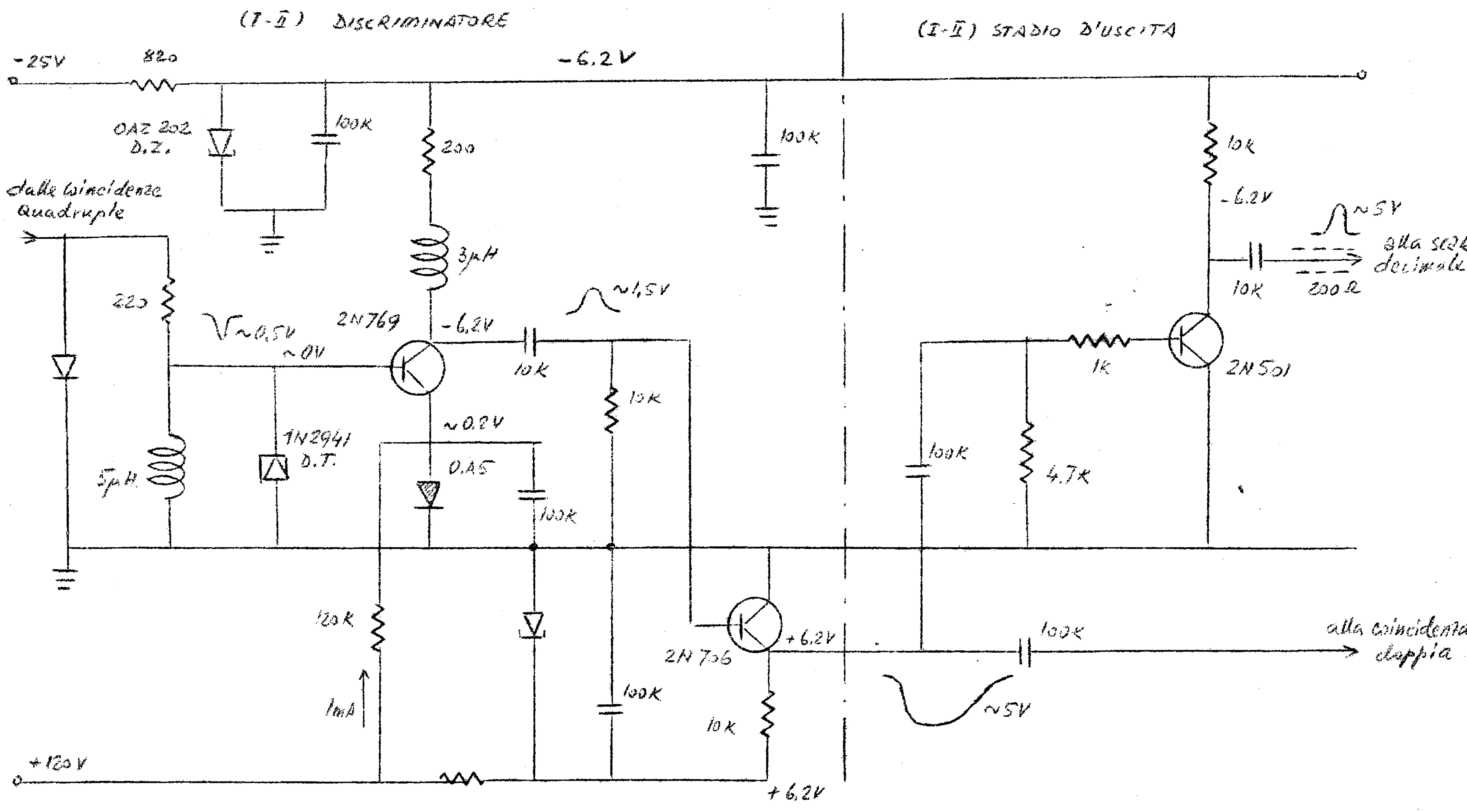

(I-II) DISCRIMINATORE
(I-II) STADIO D'USCITA
-25V
820
-6.2V
OAZ 202
D.Z.
100K
200
10k
dalle coincidenze
Quadruple
3μH
-6.2V
~5V
10K
200 Ω
220
~1,5V
2N769
-6.2V
~0V
10K
1K
2N501
10K
~0.2V
1N2941
D.T.
100K
4.7K
5μH
0.A5
100K
120K
100K
alla coincidenza
doppia
+6.2V
2N706
1mA
100K
~5V
10K
+120V
+6.2V

FIG. 5

ducting OA5. The output at the collector of the 2N769 saturated a cut off 2N706 giving a standard output. If a 2N501 is used instead of the 2N769 , the 5 ma tunnel diode does not trigger but produces a spectrum of pulses.

To convert the fourfold coincidence into a three fold, twofold or single, a switch on the ground side of the 200 ohm at the input could bias into cutoff the diode above.

Various tests were made with a 20 ma tunnel diode instead of a 5 ma diode to improve the triggering characteristics of the discriminator. In test number 1) the 220 ohm resistor in series was replaced by 68 ohm to have a threshold of $1.42\ V = 20 \times 10^{-3} \times 68 + 0.06$. R was changed to have a current of 28 ma. In this case a triple at the input of amplitude greater than 15 V triggered the discriminator due to decrease in the ratio of fourfolds to threefolds. In this case R' was 68 ohm. Another trouble with a small R' is that the pulse in the 200 ohm cable used as a shorting stub, sees at the input of the coincidence circuit the 200 Ω resistance in parallel with the 68 Ω until the diode is cut off. This produces a reflection which returns to the short and thus returns again. This series of reflections produces a rather long dead time at the inputs.

Test number 2) was to polarize the 20 ma tunnel diode at 10 ma. Thus a series resistor R' of 120 ohm could be used. The resistor R was adjusted to draw 14 ma. Here a small pulse of 25 mv on the ground combined with a triples pulse below the threshold triggered the diode when the triples input was greater than 15 volts, thus triggering the tunnel diode.

Test number 3) consisted of a step down autotransformer of 8 turns in the primary to 3 in the secondary, with the primary connected to the coincidence and the secondary to the 20 ma diode. The resistor R was adjusted to draw 10 ma. With this arrangement, the threshold for fourfolds was 1,4 volts and a triple of 25 volts did not trigger the discriminator. The trouble however was that the impedance of the tunnel diode as seen in the primary of the transformer was still rather small causing reflections at the input of the coincidence.

Test number 4) consisted of using a 2N769 emitter follower with 39 ohm 's in the emitter in series with the 20 ma diode. Here the threshold was about 1,3 volts and 25 V triples did not trigger the discriminator, R was adjusted to draw 7 ma. In this last test, the impedance seen at the input is close to 200 ohm so that multiple reflections are avoided.

Actual Circuit Used

In figs. 1, 2, 5 and 6 are shown the circuit used. In fig. 7 is shown the high voltage plateaus taken with 2 m shorting stubs instead of the normal 1 m ones to diminish the effect of the time shift caused by the change in high voltage. Fig. 8 shows the curve of the counting rate VS. The delay of one of the four inputs of the fourfold coincidence. This curve has the form of a trapezoid with the flat region of 2 ns at the base on each side. 2τ the full width at half maximum is thus about 7 ns.

The scintillators used in the counters varied in size from 5 x 15 cm to 30 x 30 cm in the fourfold coincidence. The effect of the size on the scintillators is to introduce a jitter in the timing of about 2ns, which accounts in great part for the sloping sides of the trapezoid.

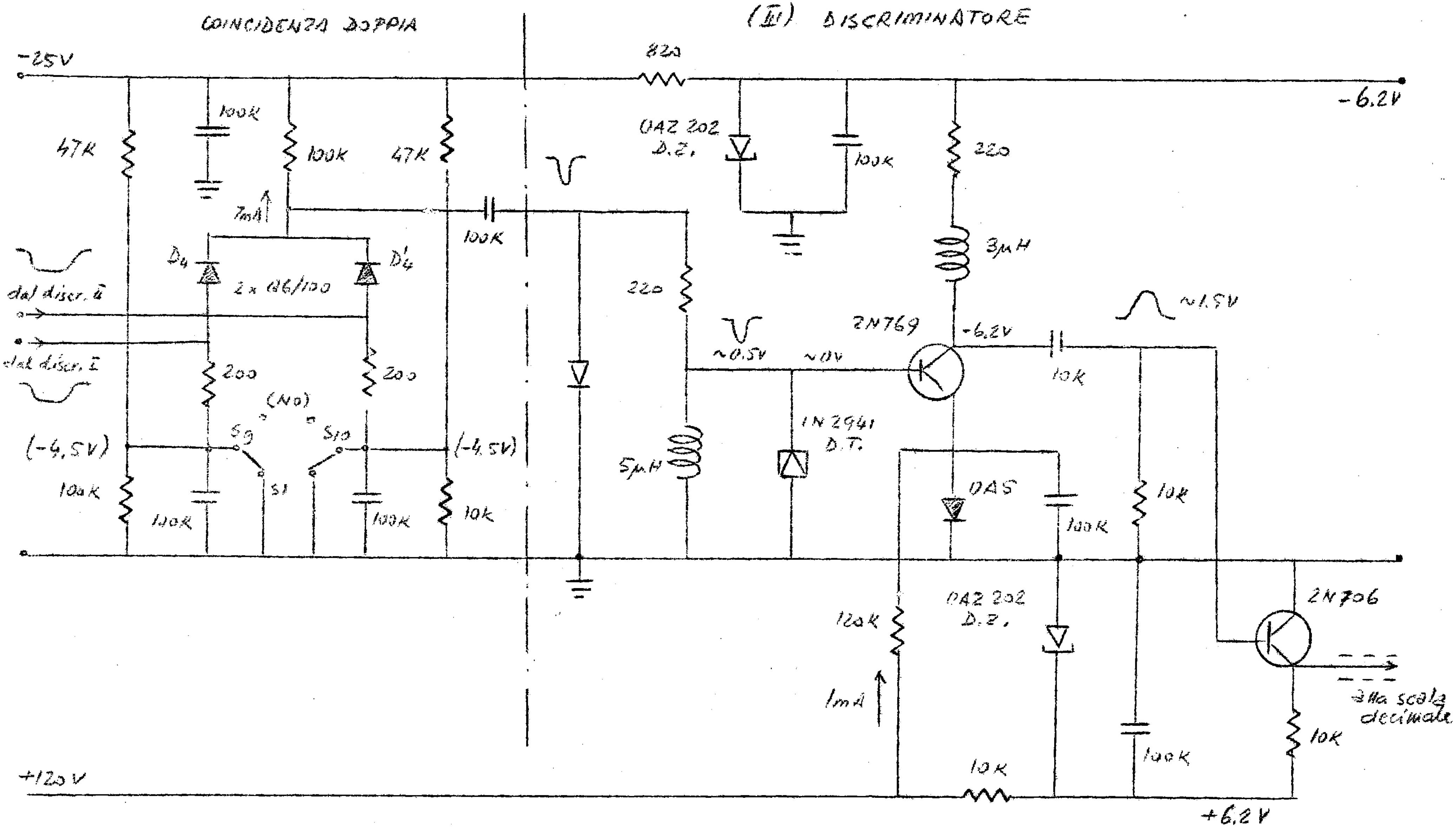
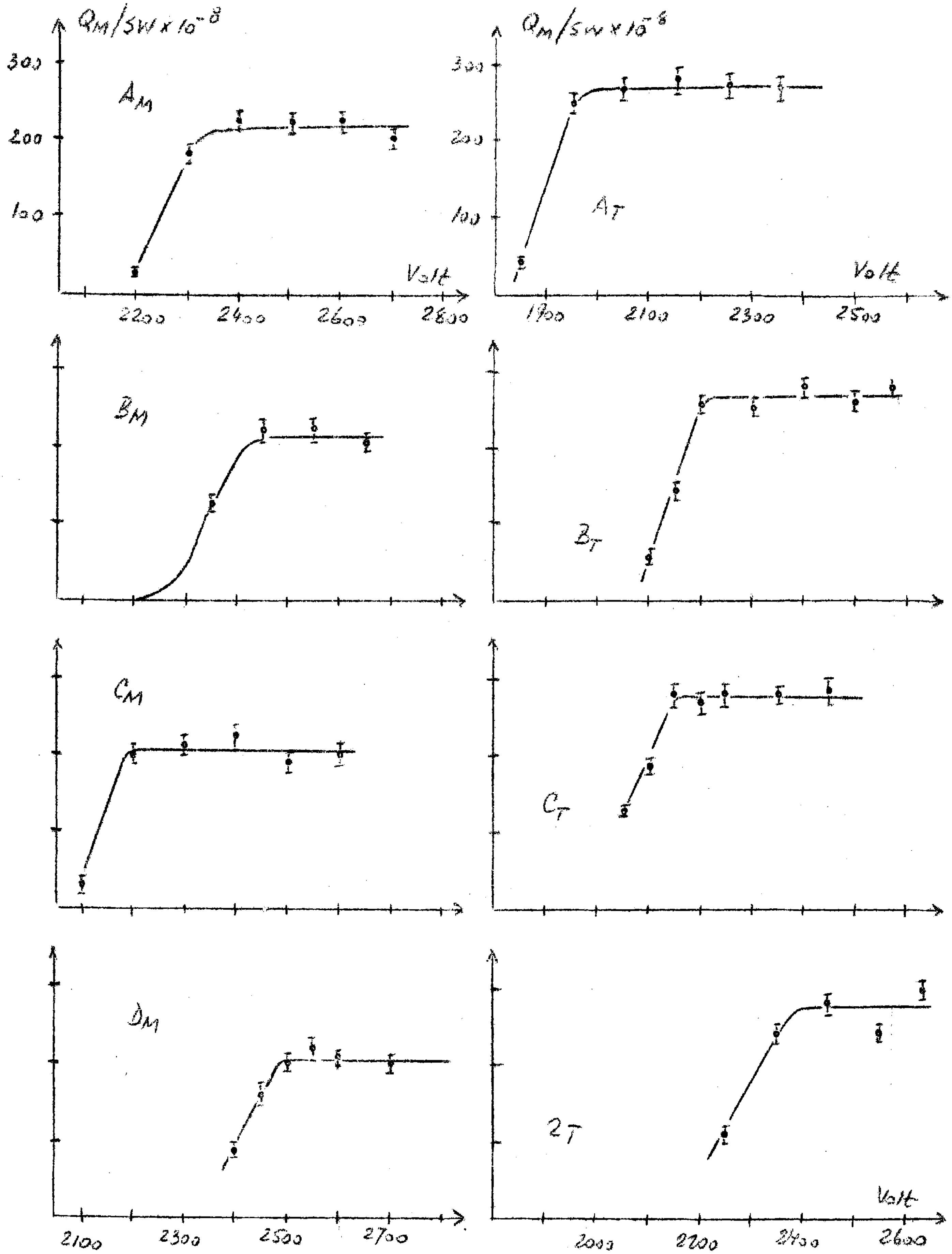

COINCIDENZA DOPPIA
(IV) DISCRIMINATORE
-25V
-6.2V
+120V
+6.2V
47K
100K
100K
47K
82Ω
OAZ 202
D.Z.
100K
220
3μH
7mA
D4
D'4
2 x OA6/100
dal discr. II
dal discr. I
200
200
(NO)
S9
S10
S1
(-4,5V)
(-4,5V)
100K
100K
100K
10K
100K
220
5μH
~0.5V
~0V
2N769
-6.2V
~1.5V
10K
1N2941
D.T.
OA5
100K
10K
120K
OAZ 202
D.Z.
1mA
10K
100K
2N706
10K
alla scala decimale

FIG. 6



QM/SW x 10^-8
300
200
100
AM
Volt
2200
2400
2600
2800
QM/SW x 10^-8
300
200
100
AT
Volt
1900
2100
2300
2500
BM
BT
CM
CT
DM
2T
Volt
2100
2300
2500
2700
2000
2200
2400
2600

FIG. 7

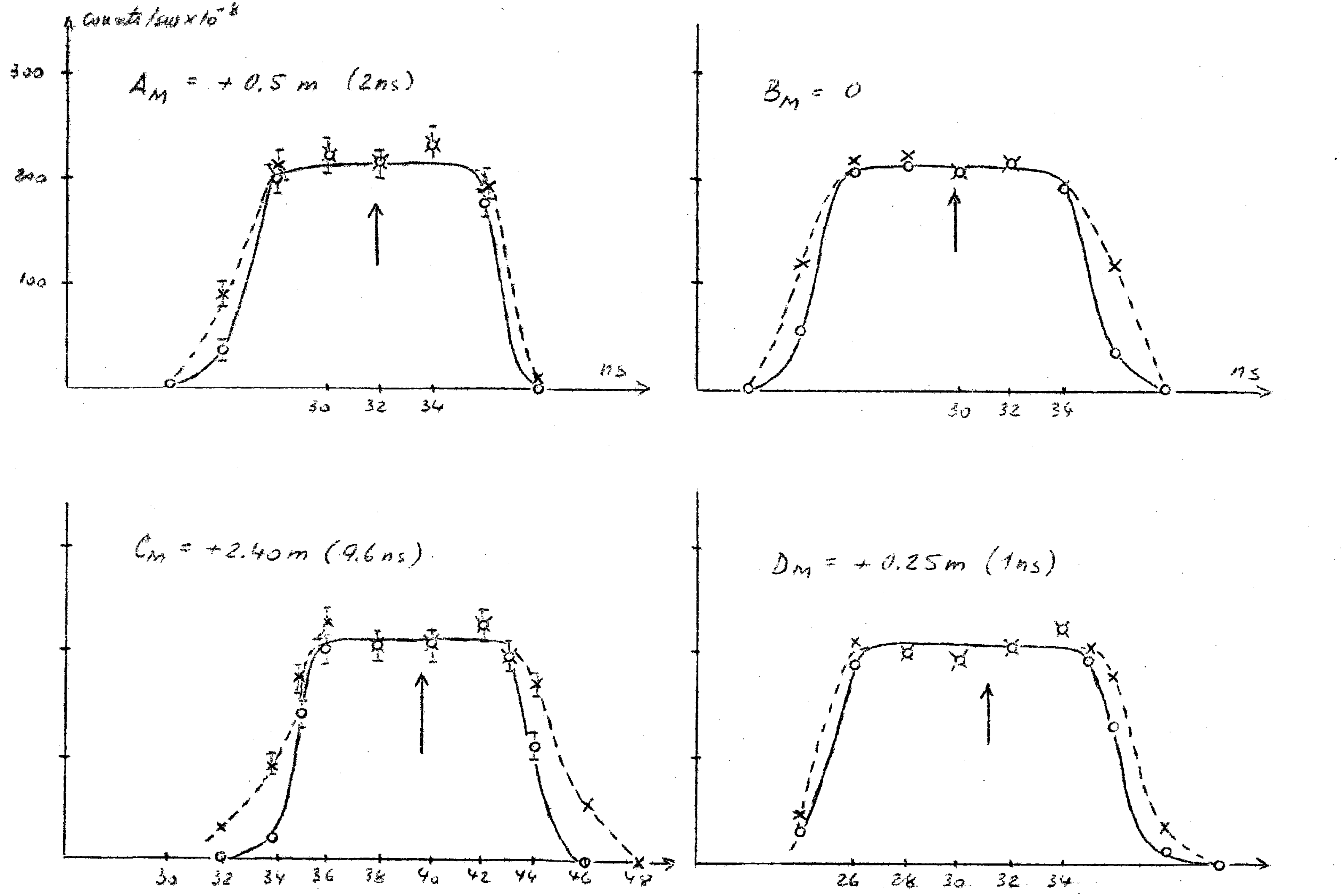

counts/sus × 10⁻⁸
300
200
100
A_M = + 0,5 m (2ns)
ns
30 32 34
B_M = 0
ns
30 32 34
C_M = +2,40m (9,6ns)
30 32 34 36 38 40 42 44 46 48
D_M = + 0,25m (1ns)
26 28 30 32 34

FIG. 8 a)

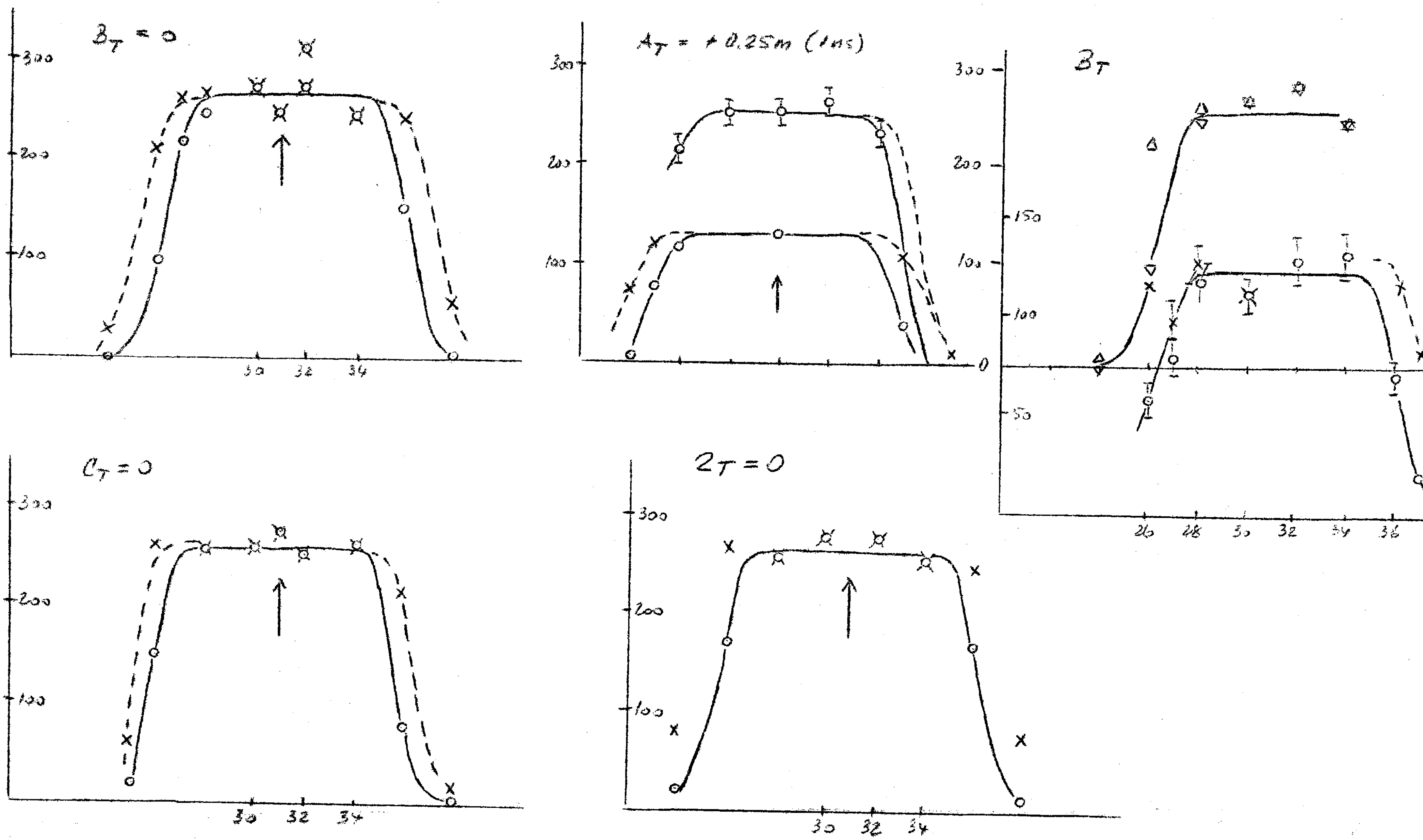


FIG. 8b)