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L. Bergamasco, C. Castagnoli, B. D'Ettore Piazzoli, A. Piano, P. Picchi and R. Visentin: LARGE AREA SPARK CHAMBERS ASSEMBLY FOR UNDERGROUND COSMIC RAY COMPONENTS.

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L. Bergamasco[(x)], C. Castagnoli[(x)], B. D'Ettorre Piazzoli[(x)], A. Piano[(x)], P. Picchi and R. Visentin: LARGE AREA SPARK CHAMBERS ASSEMBLY FOR UNDERGROUND COSMIC RAYS COMPONENTS. -

1. - INTRODUCTION. -

In this note we describe the experimental apparatus which is now working in the Monte Cappuccini Station (Torino) (underground depth 40-300 m. w. e.) to investigate the properties of the energetic penetrant and semi-penetrant component of the cosmic radiation. Another set up with the same features but larger dimensions will be soon at work in the Mont Blanc Station (3000-16000 m. w. e.). The two assemblies will allow a correlation between the two sets of results obtained at shallow and great depths. The following is a brief list of the aims[(1)] of these experiments:

- Investigation of the correlations between the secondaries of the N-N interactions at very high primary energies ($10^5 < E_p < 10^8$ GeV) by detecting the muon bundles and the parallel penetrating particles (P. P. P.);
- Measurement of the mean transverse momentum $\langle p \rangle_\perp$ of the secondaries of the N-N interactions as a function of E_p by means of the decoherence curve;
- Detection of heavy particles with mass M_h = 10-30 GeV, inelasticity $k_h = M_N k_N / M_h$ and mean free path $\lambda_h = 3\,\lambda_N$ (where the subscript N refers to the nucleon);
- Measurement of the muon fluxes at large zenithal angles and on the vertical corresponding to the same depths;
- Study of the muon interactions, and namely:
  a) vertical and horizontal electromagnetic bursts,
  b) muoproduction in the deep inelastic scattering region;
- Investigation of the properties of neutrino induced muons.

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2. - APPARATUS. -

The apparatus consists of two range telescopes of size 144 x x 144 x 206 cm^3 (Fig. 1); each of them is costituted by six bigap chambers and six lead layers (thickness 5 cm) with two scintillation counters (size 140 x 140 x 3 cm^3) placed at the top and the bottom. The total absorber thickness is = 450 gr cm^{-2}.

2.1. - Scintillation Counters.

Each scintillation counter consists of two equal plastic scintillators NE 102 A 70 x 140 x 3 cm^3. Every scintillator is watched by two 56 AVP photomultipliers with plexiglass light pipes (70 x 40 x 5 cm^3) placed at right angle (Fig. 2).

All the counters have been tested with minimum ionizing cosmic rays muon: we have detected the charge spectrum by summing the dinode N. 14 output currents from the two p. m. watching the scintillator (Fig. 3). Each pulse amplitude in the spectrum has been digitized and recorded in a picture together with the track of a particle passing through the telescope. Fig. 4 shows the counter response to the uniformity test. From the spectrum width of Fig. 3 we obtain the mean light collection efficiency[2] of the counter $\eta \approx 1\%$.

2.2. - Spark Chambers.

The main features of each bigap are:

- Efficient area 140 x 140 cm^2;
- Aluminium plates 5 cm thick;
- Gap width 0.75 cm;
- Perspex frames;
- He sealed at atmospheric pressure.

Each bigap is triggered by a 10 KV HV pulse obtained by discharging a 15 Kpf capacitance with a spark gap.

A spark box (Fig. 5) provides the HV pulse to six output channels, connected to each bigap of a telescope by means of a 50 ohm HV coaxial cable.

The single gap efficiency for minimum ionizing particles and using the gas at atmospheric pressure is $\sim$ 95 %. The bigap efficiency is $\sim$ 100 %.

3. - LOGIC. -

The functions of this apparatus are:

- to detect either single or multiple (relative delay $\lesssim$ 100 ns) particles traversing one or both telescopes;

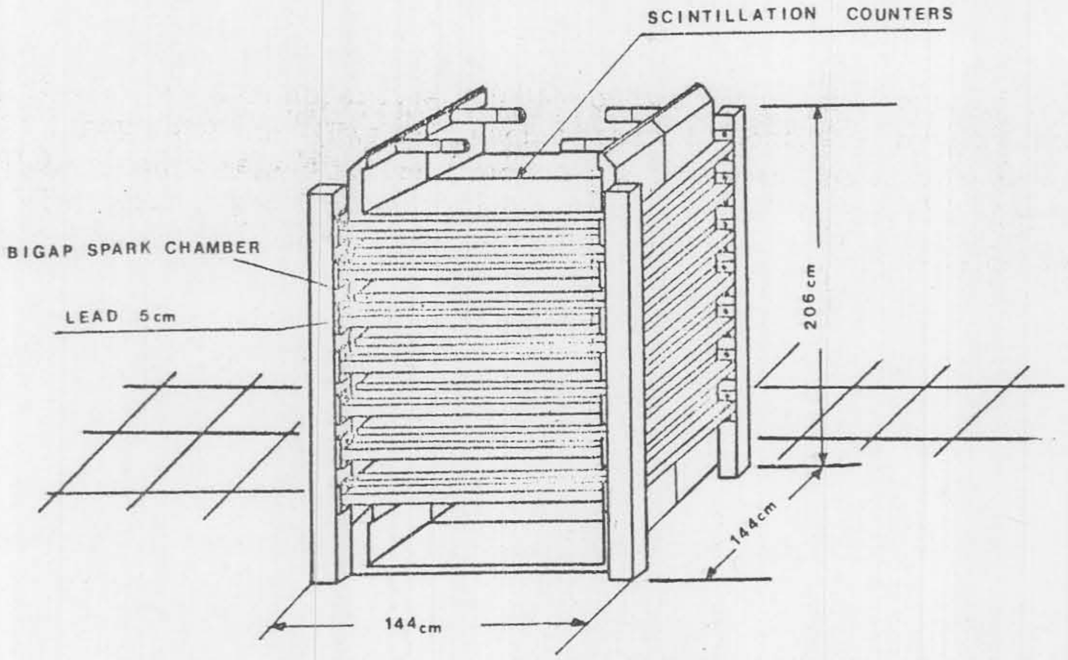

FIG. 1 - A range telescope in the Monte Cappuccini Station.

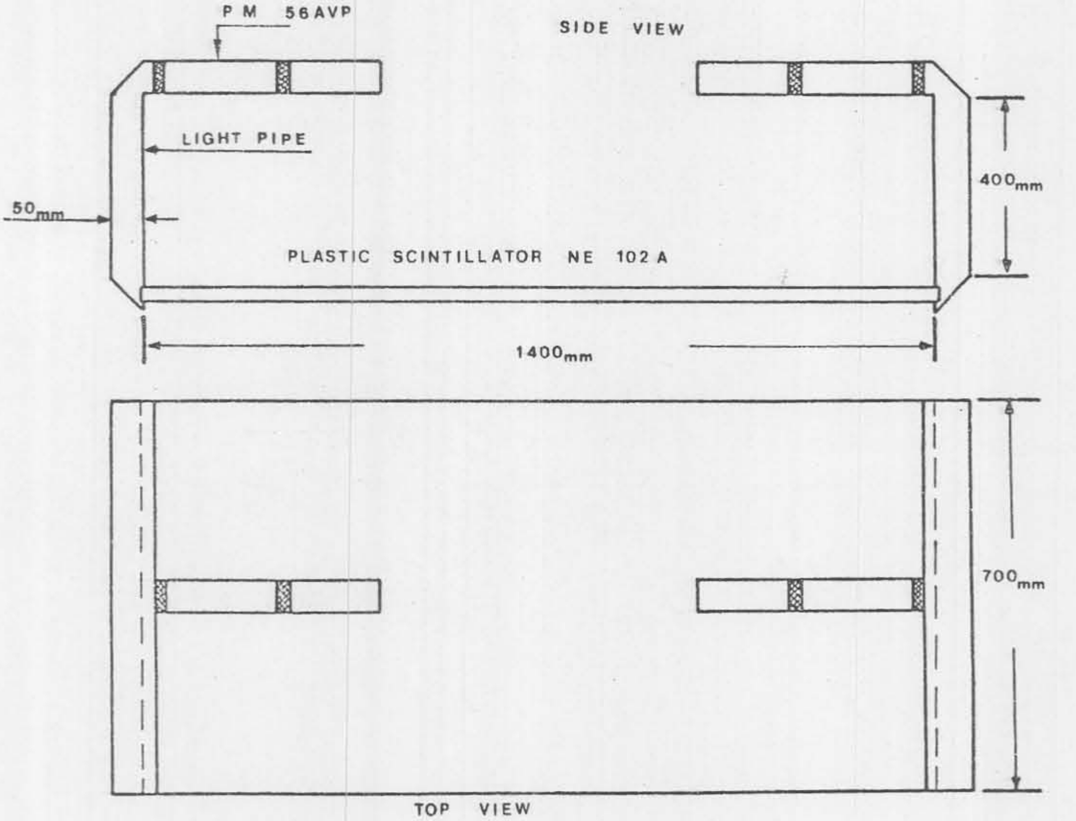

FIG. 2 - The scintillation counter : the shape of the lightpipes and the position of the 56 AVP p. m. awoid any interference with the optical paths.

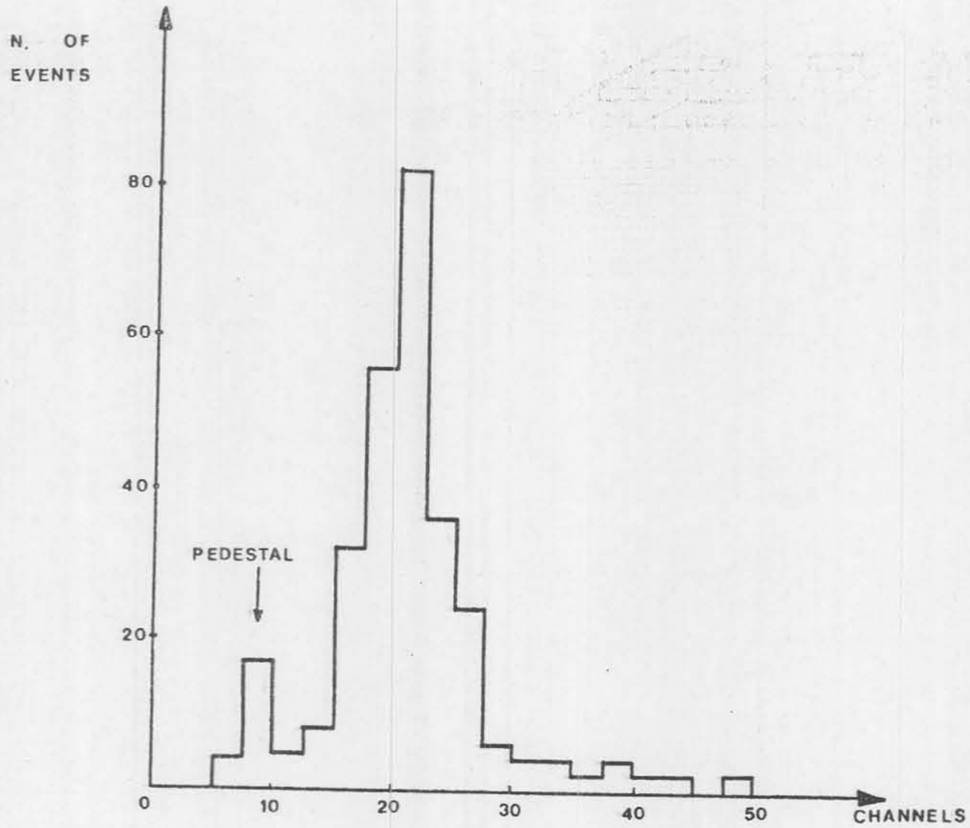

FIG. 3 - Charge spectrum from minimum ionizing particles on the overall area of the scintillator. The mean resolution (FWHM) is R ~ 40 %.

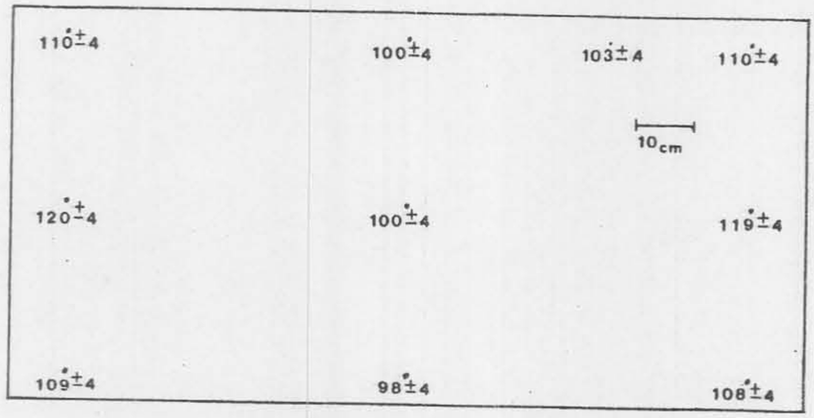

FIG. 4 - The uniformity test : the peak value of the charge spectrum normalized to the value recorded at the center of the scintillator area is shown.

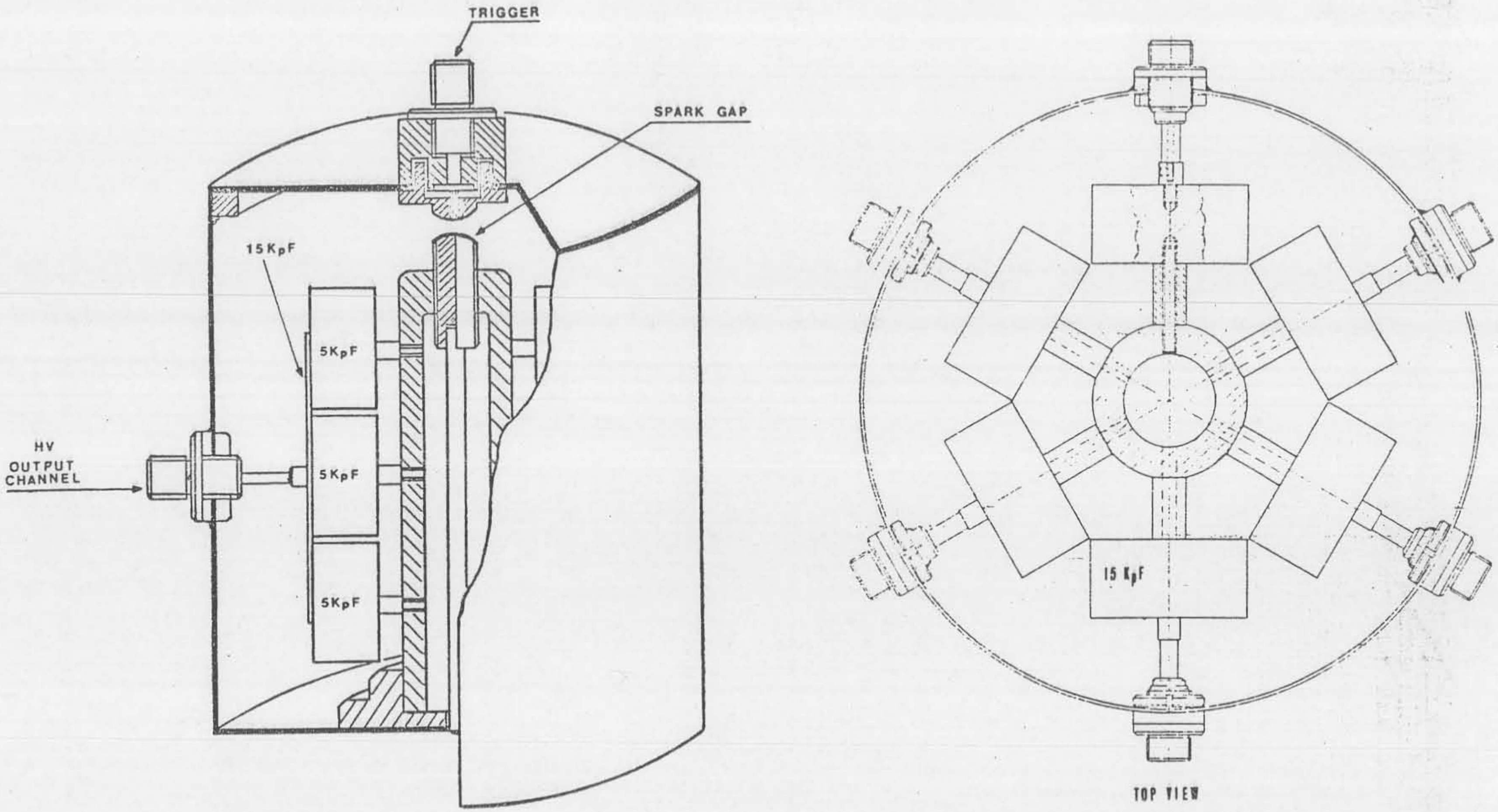

FIG. 5 - The spark box structure: a single spark gap fires the six output channels (15 Kpf each one) placed in cilindrical symmetry to minimize and equalize the series selfinductance of each channel.

- to measure the delay between contemporary particles with a resolution around 2-3 nanoseconds;
- to study the interaction secondaries with the spark chambers and the pulse amplitude analysis of the upper and lower counters.

The block scheme of the logic is shown in Fig. 6, together with the labels used.

3.1. - Logic triggers.

The spark chambers trigger of the two telescopes (MASTER) is defined as the sum of three different triggers:

$$\text{MASTER} = (C_1 \cdot C_2 \cdot C_3 \cdot C_4) + (C_5 \cdot C_6 \cdot C_7 \cdot C_8) + (M_1 \cdot M_2) + M_1^{>} + M_2^{>}$$

where:

$(C_1 \cdot C_2 \cdot C_3 \cdot C_4)$	corresponds to $i \geq 2$ particles traversing contemporarily telescope 1
$(C_5 \cdot C_6 \cdot C_7 \cdot C_8)$	the same for telescope 2
$(M_1 \cdot M_2)$	corresponds to $i \geq 2$ particles traversing contemporarily both telescopes 1 and 2
$M_1 = (C_1 + C_2) \cdot (C_3 + C_4)$	
$M_2 = (C_5 + C_6) \cdot (C_7 + C_8)$	
$M_1^{>} = M_1 \cdot \left[A(C_3 + C_4) > Q_1\right]$	corresponds to single particle ($i = 1$) interacting in telescope 1. $A > Q_1$ sets a condition on the charge amplitude of the lower counter
$M_2^{>} = M_2 \cdot \left[A(C_7 + C_8) > Q_2\right]$	the same for telescope 2.

3.2. - High resolution time analysis of the $M_1 \cdot M_2$ coincidence.

The $M_1 \cdot M_2$ trigger makes possible an accurate analysis of the relative delay of two particles. This is accomplished with a time to amplitude converter following the scheme shown in Fig. 6: the start and stop signals come from the upper counters after reducing the time fluctuations due to the light transit times (in the large area scintillators) by means of a time jitter compensator. Fig. 7 shows a typical time resolution curve (FWHM $\approx$ 2.5 ns) of the counters C_1, C_2, C_3 and C_4 obtained placing a reference scintillator of area $30 \times 30 \times 2\ \text{cm}^3$ at the

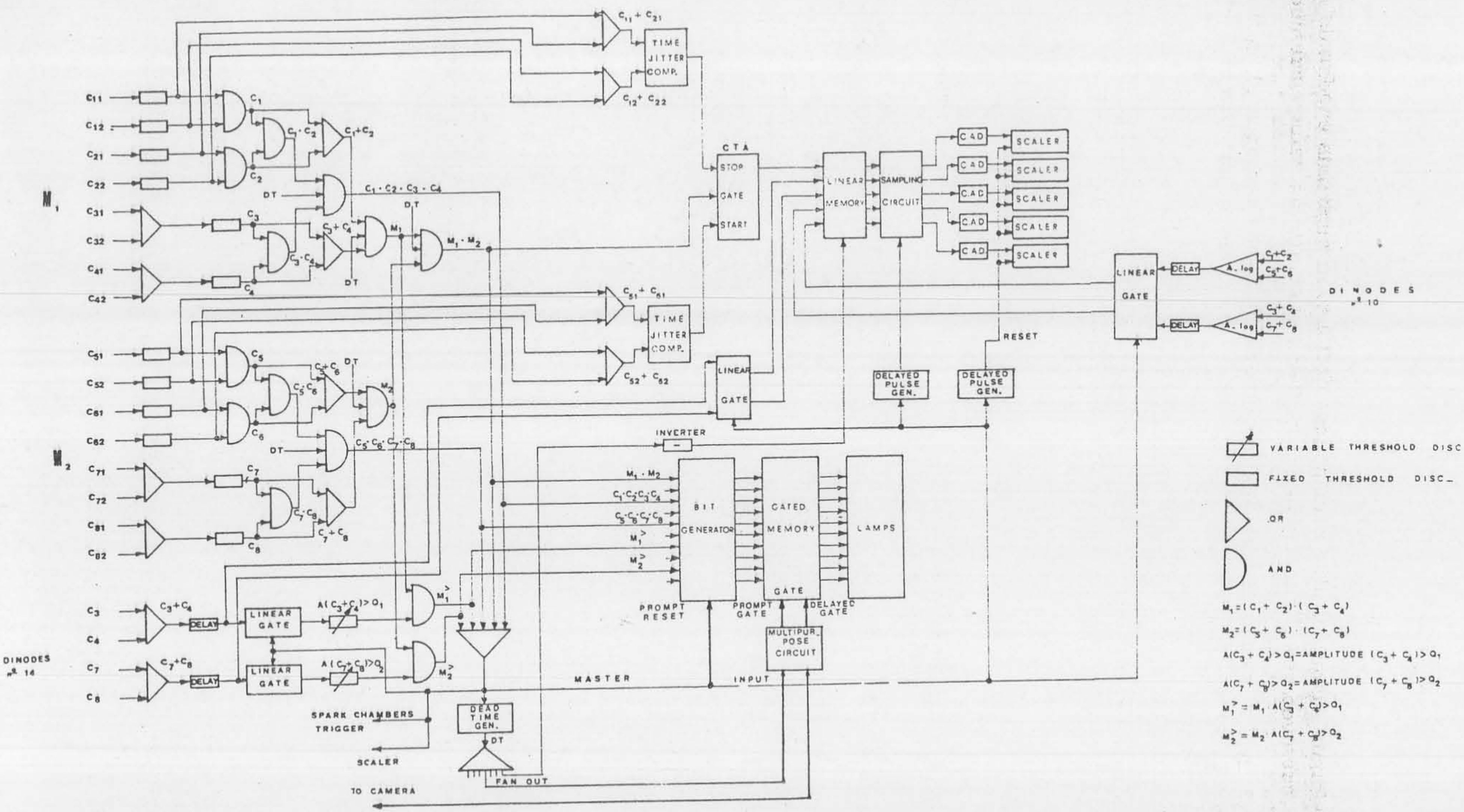

FIG. 6 - The block scheme of the logic.

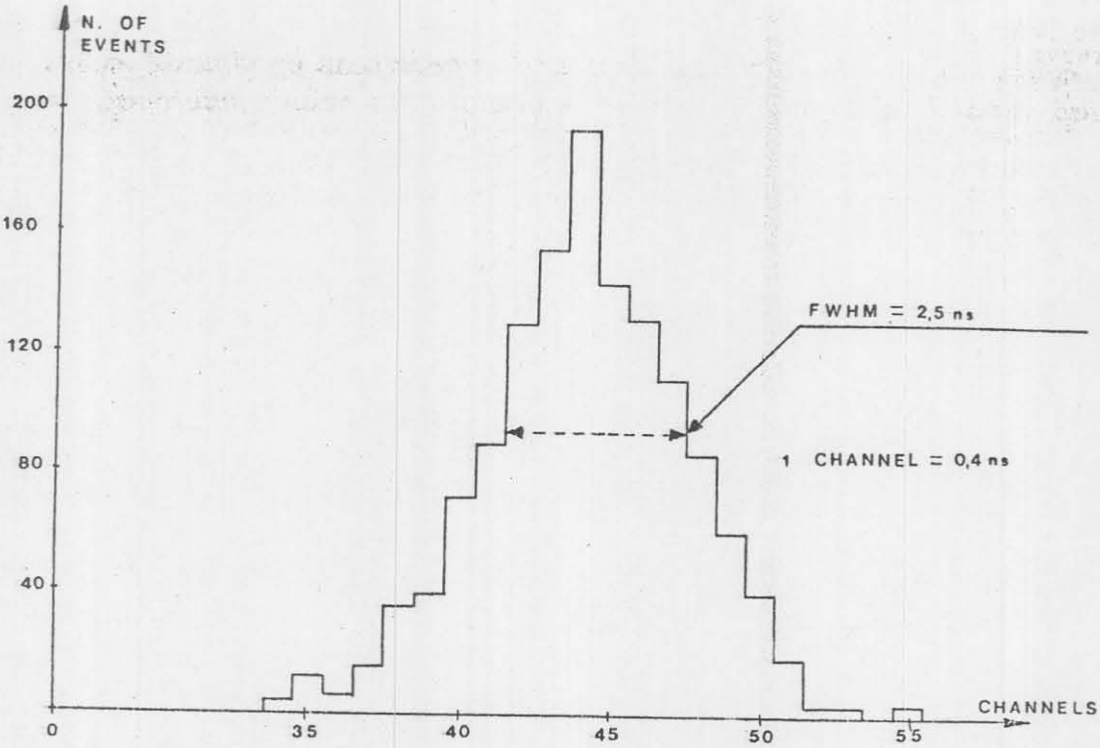

FIG. 7 - The prompt resolution curve obtained by measuring with a time to amplitude converter the relative delay between a $30 \times 30 \times 2$ cm^3 and a $70 \times 140 \times 3$ cm^3 scintillation counter is placed in the center of the greater one. The FWHM is 2.5 ns; the resolution of the large counter is better than this value.

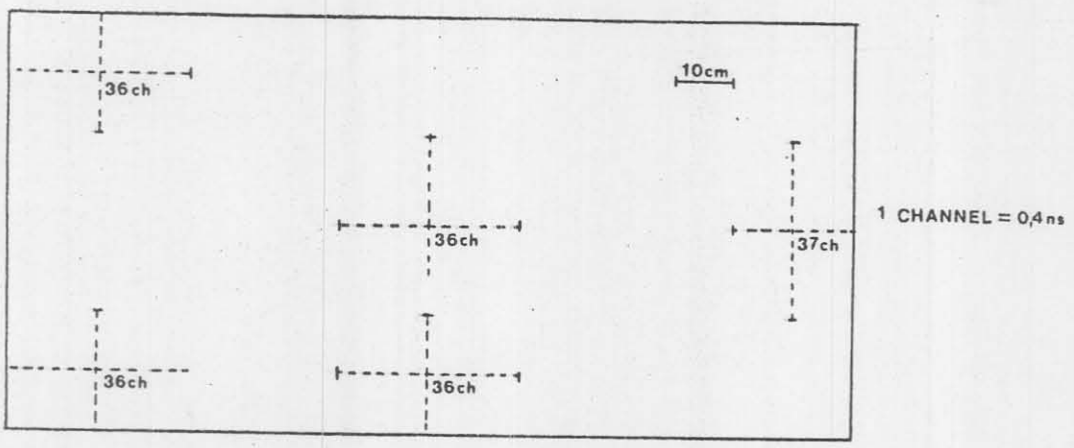

FIG. 8 - The uniformity test of the high resolution timing of the $M_1 \cdot M_2$ coincidence.

center of each of them. Measurements over different regions of the same counter show that the maximum shift of the time spectrum peak is ≤ 0.5 ns and the resolution is unchanged (Fig. 8). The resolving power of this time analysis is then ~ 3 ns.

The time distribution of the relative delays of muon pairs obtained experimentally is shown in Fig. 9 : the agreement with the distribution calculated by the Monte Carlo[3] method using an isobar-pionization model for the N-N collision is satisfying.

3.3. - Amplitude Analysis.

The lower counters of both telescopes undergo two simultaneous charge analysis :

- Linear : the sum of the current signals out of the 14th dinode of the two p.m.'s of each counter is integrated, while an analogous "fast" analysis of the charge signal gives the $M_1^>$ and $M_2^>$ triggers (Fig. 6);
- Logarithmic : the sum of the currents out of the 10th dinodes is integrated and the total charge explored by means of a logarithmic chain (Fig. 6).

4. - ELECTRONICS. -

Part of the circuits (namely those concerned with the data translation into binary form, the amplitude analysis chain and the time jitter compensator) has been suitably designed, all the other electronics (discriminators, coincidences, triggers, T-A converters, delaies, attenuators, and so on) follows the Frascati NIM standard.

5. - OPTICS. -

Each telescope is seen from two adjacent sides (90° stereoscopy); the four views are focalized by a many mirrors system on a single mirror wich is then photographated (Fig. 10).

6. - PHOTOGRAPHIC REGISTRATION. -

Every picture contains :

- the four views of the two telescopes;
- the information in binary form on the type of trigger and on the counters involved;
- the digital information on the delays measured with the A-T converter;

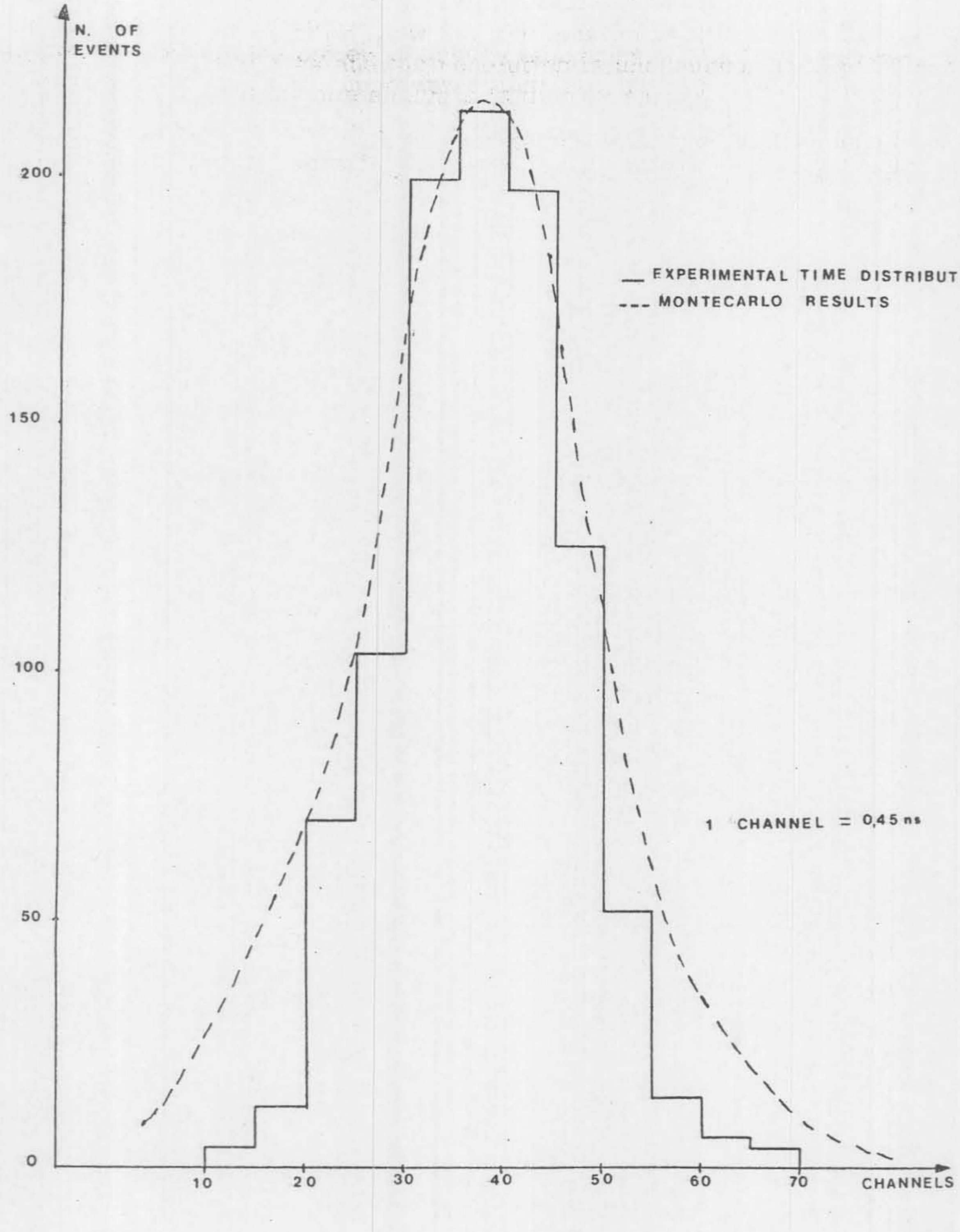

FIG. 9 - The experimental (full line) and calculated (dashed line) time distribution of the relative delays of muon pairs on the two telescopes.

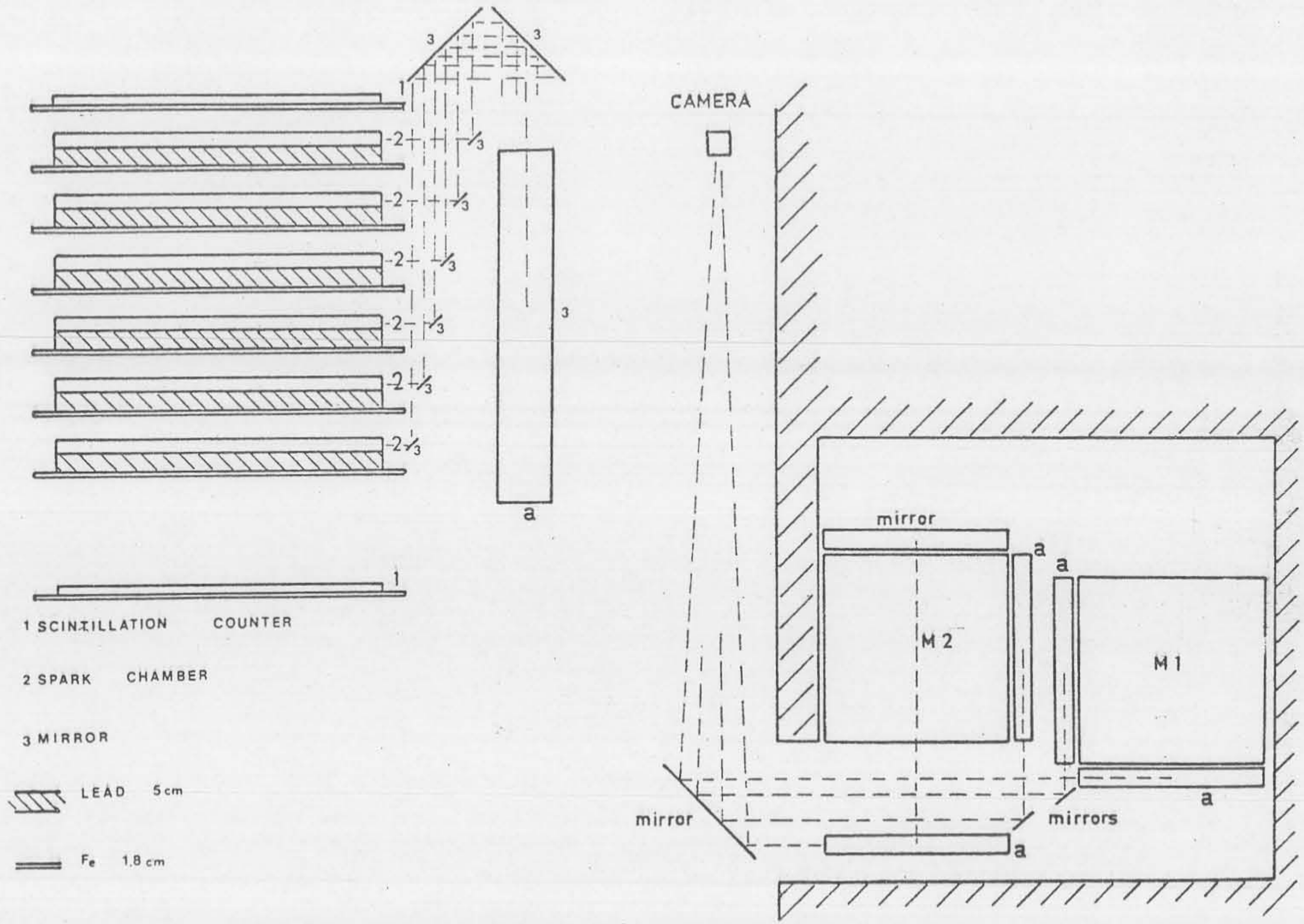

FIG. 10 - Schematical view of the optical paths.

- the digital information on the linear amplitude analysis ;
- the digital information on the logarithmic amplitude analysis ;
- sequence number and date.

7. - TELESCOPE FACTORS. -

The telescope factors formula(4) relative to the different triggering conditions is :

$$_i = \int_0^x \int_0^y \int_0^x \int_0^y \frac{1}{z^2} \cos \theta^{\rho+3+i} \left\{ \left[x - |x-x'| \right] \left[y - |y-y'| \right] \right\}^{i-1} dx'dy'dxdy$$

where

i = multiplicity selected by the trigger,

$\cos \theta = \frac{z}{\left[(x-x') + (y-y') + z^2 \right]^{1/2}}$,

x, y, z = telescope dimensions.

In Table I are shown the telescope factors calculated for different triggering conditions.

TABLE I - Particle rate in the telescope.

	i=1 single (m^2 sr)	i=2 pairs (m^4 sr)	i=3 (m^6 sr)	i=4 (m^8 sr)	i=5 (m^{10} sr)
$C_1 \cdot C_2 \cdot C_3 \cdot C_4$ or $C_5 \cdot C_6 \cdot C_7 \cdot C_8$		8.3×10^{-2}	4.76×10^{-2}	3.066×10^{-2}	2.13×10^{-2}
$M_1 \cdot M_2$		0.605	0.707	0.923	1.293
M_1, M_2	0.653				

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