A HIGH-RESOLUTION HODOSCOPE USING A SPHERICAL MIRROR

A. Gonidec^{*)}, A. Kupferschmid and K. Kuroda^{*)}

CERN, Geneva, Switzerland

Geneva - 14 May 1976

(Submitted to Nuclear Instruments and Methods)

^{*)} Visitor from LAPP, Annecy, France.

1. INTRODUCTION

We have built a scintillation counter hodoscope to detect the position of high-flux charged particles with a space resolution of 2 mm.

In order to solve the problem of light collection from a compact array of scintillators, we have developed a new method using a spherical mirror: a magnification of scintillator image by a factor of about six allows us to match the array of scintillators to that of XP 1110-type photomultipliers.

The method has been successfully tested, and a prototype built in November 1972 showed a stable performance over two years during our counter experiments at CERN¹⁾ and the Rutherford Laboratory²⁾.

In the first part of this paper we present some fundamental quantities obtained in test experiments using a photodiode light-pulser or a ^{60}Co source.

In the second part, we describe the practical features of the hodoscope studied under the real experimental conditions.

2. TEST OF THE METHOD

We first test the principle of this hodoscope with only one scintillator strip, with the following size: 2 mm wide, 10 mm thick, 100 to 150 mm long. The experimental arrangement is shown in Fig. 1. Tests were done with a light-source, with a photodiode, and with a ^{60}Co source.

We studied the following points:

- a) The light collection efficiency was estimated by comparing the photomultiplier's pulse height when the scintillator is in the normal position, as illustrated in Fig. 1, and when it is in contact with the light guide. The 50% efficiency obtained is reasonable when we take into account the limited solid angle covered by the mirror, the shadow created by the scintillator itself, and the reflection of light on the mirror surface.
- b) In order to separate the images of two adjacent scintillators, the image quality must be good. This point was studied by moving the relative transversal position between the scintillator and the photomultiplier (X_2 direction in Fig. 1). Figure 2 shows the variation of a photomultiplier output as a function of X_2 . As we can see, we find a factor of 10 in the pulse height between the central position of the photomultiplier and the one shifted by 1 cm corresponding to approximately the centre of adjacent photomultipliers.
- c) It appears that when the scintillator is far from the optical axis of the mirror, the image quality becomes worse. To study this effect we measured the pulse-height variation by changing the angle θ (Fig. 1) of the scintillator with respect to the optical axis. The results shown in Fig. 3

indicate that the good quality of the image is conserved up to $\theta \approx 10^\circ$. We can eliminate this effect by bending the scintillators, as shown in Fig. 4, so that the maximum angle between the average light flux and the optical axis of the mirror is kept to less than 10 degrees for all the elements.

- d) We also checked the linearity of source-to-image position by observing the pulse-height variation for different positions of the scintillator (X_1 in Fig. 1). As shown in Fig. 5 the image shifts regularly as a function of the photomultiplier's position. The straight line represents the linearity of the central position of the image as a function of X_1 .

3. RESULTS OBTAINED ON BEAM PARTICLES

More critical tests have been performed with high-energy particles, using the same experimental arrangement as above. The pulse-height spectra of a photomultiplier in different conditions are shown in Fig. 6 where d is the distance between the impact point of the particles and the light output surface of the scintillator strip. The fact that for the same X_2 position the spectra for different impacts ($d = 11.0$ and $d = 5.3$ cm) are very similar indicates a good light transmission inside the scintillator.

A prototype of the hodoscope was then constructed, with the following features (Fig. 7):

number of scintillators	48
scintillator size	$1.9 \times 10 \times 150$ mm
focal length	125 mm
magnification	6.5 .

A typical pulse height is given in Fig. 8, showing two types of spectra, one coming from the observed element, and the other -- continuous background -- coming mainly from the adjacent elements, due to a halo of the images. In order to study the influence of adjacent elements, we have masked all the scintillators in the array except one, and looked at the event distribution. The results given in Fig. 9 show that the effect comes mainly from the adjacent elements as expected, and decreases quickly when the high tension goes down.

The detection efficiency of this hodoscope measured on a high-flux, charged particle beam was found to be 95%.

We also compare the natural distribution (dashed line in Fig. 10), obtained by using only one element and moving the hodoscope, to the distribution on the full hodoscope. The dashed area presents the sum of adjacents and separated multiples, and the dotted area a loss of events due to bad efficiency of the elements.

4. CONCLUSION

The hodoscope described in this paper offers a means of detecting high-energy particles with good spatial and time resolutions. The light collection through a spherical mirror has the following merits:

- A high efficiency of light collection and a large magnification factor of the image allow us to realize a millimetre resolution without the space problem of photomultiplier arrangement.
- The system once optically adjusted maintains a stable performance, because there is no delicate mechanical connection between scintillators and photomultipliers.
- It is also free from the Čerenkov background produced in a light-guide such as plexiglas.
- In addition, compared with other schemes such as a binary code or Gray code hodoscope³⁾, the hodoscope has the advantage of higher counting rate because the single rate of each counter for a given total flux is much lower in our case.

We would like to thank Messrs. A. Looten, W. Huta and M. Blanc for their help in constructing the hodoscope. We are grateful to all members of CERN-Orsay-Oxford Collaboration for their assistance in testing the system.

REFERENCES

- 1) D. Aschman et al., Phys. Letters 57B, 93 (1975).
- 2) J. Antille et al., Measurement of the polarization parameter in proton-proton elastic scattering at 8 GeV/c, to be published in Physics Letters.
- 3) D.E. Pellett et al., Nuclear Instrum. Methods 115, 135 (1974).

Figure captions

- Fig. 1 : Experimental arrangement.
- Fig. 2 : Pulse-height variation as a function of X_2 .
- Fig. 3 : Pulse-height variation as a function of the angle θ .
- Fig. 4 : Scintillator layout.
- Fig. 5 : Linearity of source-to-image position.
- Fig. 6 : Pulse-height spectra for different conditions of X_2 and d .
- Fig. 7 : Schematic drawing of the mirror hodoscope prototype.
- Fig. 8 : Typical pulse height.
- Fig. 9 : Influence of adjacent elements.
- Fig. 10 : Comparison of the natural distribution with that of the whole hodoscope.

Fig. 1

a) photodiode

b) Co 60

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10