CERN-PRE-77-143

CM-P00064266

ACCURATE TIME MEASUREMENTS WITH PLASTIC SCINTILLATION COUNTERS

F. Binon²⁾, C. Bricman²⁾, P. Duteil^{*}, M. Gouanère¹⁾,
J. Jansen²⁾, J.P. Lagnaux²⁾, J.P. Peigneux¹⁾, D. Sillou¹⁾,
M. Spighel¹⁾, J.P. Stroot²⁾ and P. Vilain^{**)}

Annecy¹⁾ (LAPP) - Belgium²⁾ (IISN) Collaboration

ABSTRACT

A plastic scintillation counter, with a useful area of (24×25) cm² and a resolution of 290 ps (FWHM) for determining the time of impact of a minimum ionizing particle, is described. The resolution may be brought down to 100 ps with smaller counters. Lower time spreads are obtained with more ionizing particles.

Geneva - 12 October 1977

(Submitted to Nuclear Instruments and Methods)

^{*}) CERN, Geneva, Switzerland

^{**}) CERN Fellow. Now at "Université Libre de Bruxelles".

1. INTRODUCTION

The accuracy in determining the time of arrival of a particle in a detector is the fundamental parameter in coincidence experiments. It is limited by intrinsic properties of the detector constituents, by geometrical constraints, and by the ionizing power of the detected particles.

The purpose of the present paper is to describe a system of scintillation counters, with a useful area of $24 \times 25 \text{ cm}^2$, which has a time jitter of 290 ps for minimum ionizing particles.

A couple of these counters have been used for detecting both decay electrons from J/ψ particles in a production experiment at the CERN Proton Synchrotron (PS), in order to handle maximum counting rates with an acceptable accidental coincidence level.

2. DESCRIPTION

The characteristics of the counters have been chosen in order to satisfy the following requirements:

- i) Detection of minimum ionizing particles: results are essentially given for this case, which is the most critical, since the greater light output of the scintillator for higher ionizing particles reduces quantum fluctuations, and thus improves the time resolution.
- ii) Use of the whole pulse spectrum, the range of which is minimized by optimizing the geometrical configuration. A special discriminator (zero crossing) compensates for amplitude-to-time correlations.
- iii) Immediate result, without any further off-line amplitude analysis: a standard output pulse is delivered.

NE102A plastic scintillator has been used, as it seems to ensure the best compromise between large light yield, short fluorescence decay time, and good light transmission properties. Enough light output is provided by a 2 cm thickness.

Each system is made of 12 parallelepipedic strips, which are viewed from both ends by photomultipliers [this principle has been often used in earlier works¹⁻³⁾]. They are assembled according to the set-up of Fig. 1, which ensures a good photon collection by reducing the light path inside the light guides.

The photomultipliers are 2 in. Philips XP2020 tubes. The accelerating voltage between photocathode and first dynode is maintained at a constant value by a Zener diode, in order to ensure a stable photoelectron collection.

3. ELECTRONIC SET-UP

The pulses from the three photomultipliers on each side of a counter (Fig. 2) are fed through passive mixers into zero-crossing discriminators which allow the determination of the time of arrival of the particle almost independently of the pulse height. The outputs of the two discriminators are then fed into a "mean-timer"⁴⁾, a circuit developed at CERN, which allows one to get a timing independent of the point of impact of the particle in the strip.

3.1 Timing of a counter

Figure 1 shows that each scintillator strip is coupled to a quarter of a photocathode. By carefully adjusting the voltage of the focusing dynode, the transit-time differences between the four quadrants of each phototube can be brought within ± 20 ps (Fig. 3).

Once this has been done for all six photomultipliers of a counter, these are timed, one by one, relative to an extra reference scintillation counter by varying the length of the cables connecting the phototubes to the passive mixers, in steps of 0.5 ns (see Fig. 2). Finally, a fine adjustment, within ± 20 ps, is obtained by slightly varying the high voltage applied to each phototube; 20 ps corresponds to a voltage variation of 2 V at 2 kV.

The mean-timer circuit compensates for the time differences due to the different light path lengths towards both sides of a scintillator strip with an accuracy better than ± 20 ps. It takes the scintillator light 1.75 ns to travel through a strip 25 cm long.

The amount of light as seen by one phototube, varies in the range 1 to 3, as a function of the impact of a particle along the strip.

3.2 Tests and results

The time spread of the counter has been measured with the help of two small reference scintillation counters. The electronic set-up, with an intrinsic resolution better than 20 ps, consisted of a time-to-amplitude converter, coupled to a pulse-height analyser.

Figure 4 shows the particular mounting of those test counters that give the best observed time definition. Their time resolution has been obtained by measuring the time-of-flight distribution of 700 MeV/c pions between the two counters. The observed distribution is Gaussian with (160 ± 14) ps FWHM, which corresponds to a jitter of (113 ± 10) ps for each individual counter.

Taking one of the test counters as time reference, the time of flight of particles crossing this test counter and the large counter has been registered.

The distribution is Gaussian with (245 ± 23) ps FWHM. It follows that the intrinsic time accuracy of the counter, at some fixed position along the slab, defined by the test counter, is (217 ± 20) ps. This number is independent of the relative position of the test counter; the position of the peak of the distribution is stable within 100 ps, this last small fluctuation being due to mistiming of the photocathode quadrants and imperfect compensation by the mean-timer circuit.

These factors are better brought into evidence in measurements which include the whole counter surface. Therefore, the time-of-flight distribution of 4 GeV/c negative pions between two identical counters has also been registered. Figure 5 shows the result for a beam uniformly distributed all over the counters. The distribution is nearly Gaussian with a FWHM of (410 ± 30) ps, i.e. the intrinsic resolution of a whole counter is (290 ± 20) ps.

In a 750 MeV/c test beam of positive particles, the measured resolution is 290 ps with pions and 160 ps with protons. Protons of this momentum have twice as much ionizing power as have pions of the same momentum. This indicates that the increase in the number of photoelectrons produced by the light emitted in 2 cm thick NE102A scintillator by ionizing particles, still improves significantly the time definition of the counter. Table 1 summarizes the measured resolutions.

We gratefully acknowledge the contributions of Drs. A. Bamberger, H. Brüning and R. Hartung.

Table 1

Summary of measured resolutions

Counter type	Particles detected	p (GeV/c)	Intrinsic resolution (ps)
Test counter	π	0.750	113 ± 10
Counter (locally)	π	0.750	217 ± 20
Counter (whole)	π	$\left\{ \begin{array}{l} 0.750 \\ 4.000 \end{array} \right.$	290 ± 20
Counter (whole)	p	0.750	160 ± 14

REFERENCES

- 1) G. Charpak, L. Dick and L. Feuvrais, Nuclear Instrum. Methods 15, 323-326 (1962).
- 2) D. Bollini, P. Dalpiaz, P.L. Frabetti, T. Massam, F. Navach, F.L. Navarria, M.A. Schneegans and A. Zichichi, Nuclear Instrum. Methods 81, 56-60 (1970).
- 3) C. Cernigoi, N. Grion and G. Pauli, Nuclear Instrum. Methods 131, 495-501 (1975).
- 4) B. Smith, Mean timer type N2629, preliminary specifications, CERN EP internal document, 28 March 1972.

Figure captions

- Fig. 1 : A sketch of the counter. The 12 elements of NE102A plastic scintillator ($25 \times 2 \times 2$ cm³ each) are viewed in groups of four, at each end by XP2020 photomultipliers. Small light guides of special shapes are used to collect the light between each element and the corresponding quadrant of a photomultiplier.
- Fig. 2 : Electronic set-up of a counter. The length of the cables between the photomultipliers and the passive mixer are adjusted during the timing (see the text). The time reference is given by the test counter.
- Fig. 3 : Three different measurements of the time calibration of the four quadrants on a single photomultiplier, obtained when the voltage across the focalization dynode is varied. The reference is given by an extra scintillator viewed by a small photomultiplier (see Fig. 2). The correct timing is near the one shown in (b).
- Fig. 4 : Principle of time measurement. The two extra scintillators are used to define a small beam spot (the scale between these two scintillators and the central counter is not respected, in order to show the details of the small scintillators).
- Fig. 5 : Time-of-flight spectrum of 4 GeV/c negative pions, between two identical counters. Two identical spectra are recorded on the same picture, but separated by an artificial delay of 1.4 ns.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5