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# SCINTILLATION COUNTERS FOR MULTICHANNEL TIME-OF-FLIGHT SYSTEM

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The average time resolution ($\sigma$) of about 70 ps is obtained for each of four scintillation counters at a long duration test on the CERN SPS particle beam. The counters were assembled of $2.4 \times 2.4 \times 6.0$ cm$^3$ scintillator bars and FEU-87(CsSb) type photomultipliers, both made in Russia. We observed the nonstability of mean time-of-flight (TOF) value during the runs. The maximum TOF drift contribution into the time resolution is estimated as (10-15)%.

## 1. Introduction

This work was motivated by the planning of the NA49 experiment at CERN to research the new phenomena of Pb-Pb collisions at 200 GeV/amu [1]. Upon this Proposal the time-of-flight (TOF) counter system with about 70 ps time resolution ($\sigma$) is required to improve a separation of the pions, kaons, and protons in momentum range 4-7 GeV/c to strenghten additionally the identification power provided by the time projection chambers.

The purpose of the test is to study the timing resolution of scintillation counters as a prototype for 1000-channel TOF detector wall on the negative particle wing. This is a continuation of our previous work [2,3], but the present TOF counters are manufactured of the batch of scintillators and photomultipliers procured for a mass production of the detectors.

## 2. Counter design

We tested four TOF counters consisting of the plastic scintillator and the FEU-87 (CsSb) photomultiplier (PMT), both made in Russia. The scintillator was polystyrene doped with 3.5 % PBD (phenyl-biphenyl-oxadiazole). Details of properties of this scintillation material are given in ref. [4]. Dimensions of the scintillation block were 6 cm (length) × 2.4 cm (width) × 2.4 cm (thickness in beam direction). In order to obtain the best value of the time resolution, we did not use the light guide. The PMT was coupled

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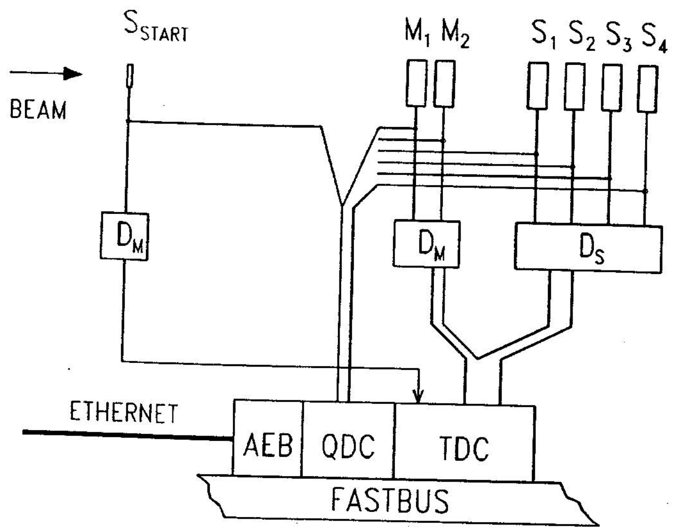


Fig.1. Schematic diagram of the measurements.

directly to the scintillator bar with an optical grease. The scintillator was wrapped in a black paper. The PMT has a 2 cm diameter CsSb photocathode and 11-stage dynode chain. We used special non-linear voltage divider [2] in this experiment. A voltage between the anode and the cathode of 2200 V provides electron gain of about $10^7$ and output anode pulse of about 2 V amplitude and 3.5 ns rise time for minimum ionizing particle.

## 3. Experimental setup

The counters were tested in the H2 beam line of the CERN SPS north area with the following beams: protons of 200 and 30 GeV/c momenta and electrons of 20 GeV/c momentum. A schematic diagram of the measurements is shown in Fig.1. Triggering was performed by three-fold fast coincidence of the start counter $S_{Start}$ (quartz plate with Valvo XP2020 photomultiplier) and $M_1$ and $M_2$ counter signals. The counters under the test ($S_1$, $S_2$, $S_3$, and $S_4$) were placed just close to the $M_1$ and $M_2$ counters. All electronics were placed in the NA49 counting room, and signals from the counters passed through 33 m long Suhner S03272 coaxial cables and then were splitted into two equal portions: one for timing and the other one for charge measurements. Constant-fraction discriminators $D_S$ (4F-163, Dubna designed) and $D_M$ (Philips Scientific PS715) are attached to the counters $S_1$..$S_4$ and $S_{Start}$, $M_1$, $M_2$, respectively. Time between a signal of the start counter and signals of the counters under the test ($\mathcal{T}_{Start-S_i}$, i=1..4) as well as integrated charge ($Q_{S_i}$) of all signals were measured by FASTBUS TDC (Philips Scientific 10C6) and QDC (LeCroy 1882F). Data from TDC and QDC were read out by intelligent FASTBUS master AEB (Aleph Event Builder) and then transferred to SUN SPARCstation.



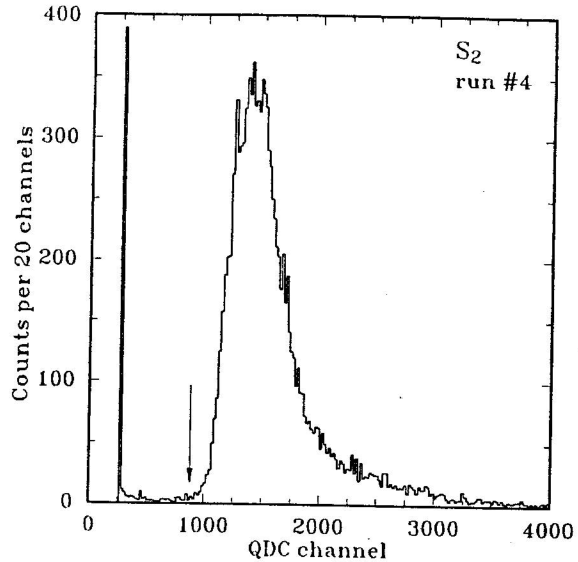


Fig.2. Integrated charge spectrum measured with $S_2$ counter. The arrow shows the bound for elimination of background.

Table 1. The time resolution ($\sigma$) of individual counters (CERN test).

| Run | #1 | #2 | #3 | #4 | #5 | #6 |
|---|---|---|---|---|---|---|
| Beam | 20 GeV/c electrons | 200 GeV/c protons | | | | 30 GeV/c protons |
| $\sigma_1$, ps | $73 \pm 12$ | $70 \pm 8$ | $73 \pm 9$ | $89 \pm 5$ | $89 \pm 4$ | $60 \pm 5$ |
| $\sigma_2$, ps | $72 \pm 13$ | $82 \pm 7$ | $82 \pm 10$ | $79 \pm 5$ | $78 \pm 5$ | $80 \pm 3$ |
| $\sigma_3$, ps | $100 \pm 9$ | $67 \pm 8$ | $74 \pm 9$ | $83 \pm 5$ | $89 \pm 4$ | - |
| $\sigma_4$, ps | - | $51 \pm 10$ | $58 \pm 10$ | $68 \pm 5$ | $70 \pm 5$ | $70 \pm 4$ |

## 4. Analysis and results

Processing the data we eliminated a background by rejecting the events with the integrated charge being smaller than the lower bound for minimum ionizing particles (see Fig.2). When the elimination was applied about 5-10% of the events were excluded from the data.

Some uncertainties in the beam contents and its momentum spread lead to the additional dispersion of the TOF value $\mathcal{T}_{Start-S_i}$ measured at a long distance between the start counter and the counters under the test. By this reason as well as in order to exclude the influence of the start counter resolution we deal with the time differences for each two test counters :

$$\mathcal{T}_{S_i-S_j} = \mathcal{T}_{Start-S_i} - \mathcal{T}_{Start-S_j} \qquad (1)$$

Fig.3a shows typical scatter plot $\mathcal{T}$ vs the integrated charge $Q$ (the average value of $\mathcal{T}$ is adjusted to be zero). We observed that the $\mathcal{T}$ value depends on $Q$ even for

Table 2. The time resolution ($\sigma$) of individual counters (Dubna test).

| Run | #1 | #2 |
|---|---|---|
| Beam | 6 GeV/c | protons |
| $\sigma_2$, ps | $68 \pm 10$ | $73 \pm 10$ |
| $\sigma_3$, ps | $57 \pm 12$ | $61 \pm 12$ |
| $\sigma_4$, ps | $76 \pm 9$ | $74 \pm 10$ |

timing with the constant fraction method. This is well known time-walk effect and its magnitude is up to 200 ps in our case. As an attempt to correct the TOF measurements for this effect, fits to the data in the scatter plots were performed for each counter. The following function was used :

$$\mathcal{T}(Q_{S_i}) = P_{0i} + P_{1i} \cdot Q_{S_i} + P_{2i} \cdot Q^2_{S_i} + P_{3i} \cdot Q^3_{S_i} + P_{4i} \cdot Q^4_{S_i} \qquad (2)$$

where $P_{0i}..P_{4i}$ are the parameters for each counter.

Fig.3b shows a scatter plot between the corrected $\mathcal{T}$ and $Q$. From this scatter plot we see that the time-walk effect has disappeared.

To obtain time resolutions $\sigma_{S_i-S_j}, (i,j = 1..4,\ i \neq j)$ the $\mathcal{T}_{S_i-S_j}$ spectra were fitted with a Gaussian distribution (see for example Fig.4). Finally, we evaluated optimum values of the time resolutions $\sigma_i$ for each individual counter using an asymptotic method. Table 1 shows the time resolutions for six runs distributed uniformly in time during 10-days test (about 60 runs). The errors presented are statistical ones.

We note that the measured time resolutions are rather different for the same counters in various runs. One possible explanation of this fact could be connected with a time drift of the counters. Fig.5 shows a fluctuation of a mean value of $\mathcal{T}_{S_1-S_4}$ between pulses from $S_1$ and $S_2$ counters during 10 minutes run #3. The typical time drift is estimated of 10 - 30 ps per run. However we observed a few runs with more unstable behaviour of some counters. For example, the time drift of $\mathcal{T}_{S_2-S_3}$ (determined mainly by the contribution of the counter $S_3$) in run #3 was about 80 ps. The time resolution $\sigma_3$ extracted from initial 40% of the run events (with relatively low time drift) is equal to $66 \pm 7$ ps ($\sigma_3 = 74 \pm 9$ ps for whole run).

A special test to research the time drift phenomenon was done farther [3] and we arrive to the conclusion that it caused primarily by the high voltage power supply of the photomultipliers. As a result, the drift in the TOF measurements was practically eliminated during the few hours runs when the counters were provided with the common high voltage power supply. At the same time, the smooth behaviour of the measured drift convince us sure it is reasonable to use the laser calibration system [1,5] for the TOF data correction.

Three months later we had a chance to repeat the TOF measurements with the same $S_2$, $S_3$, and $S_4$ counters at the JINR Synchrophasotron beam. The beam was 6 GeV/c protons. Each test run duration was approximately 4 hours. The detector time



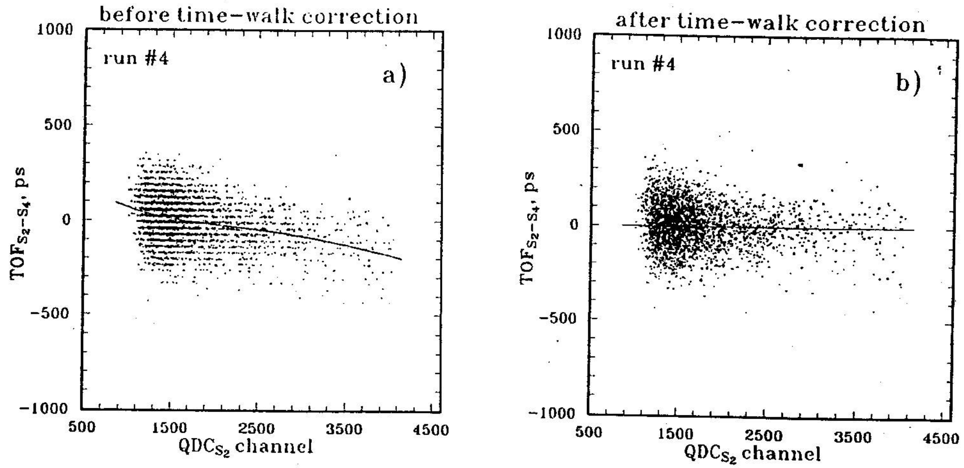


Fig.3. Scatter plot between the time-of-flight $\mathcal{T}_{S_2-S_4}$ and the integrated charge $Q_{S_2}$ before (a) and after (b) the time-walk correction.

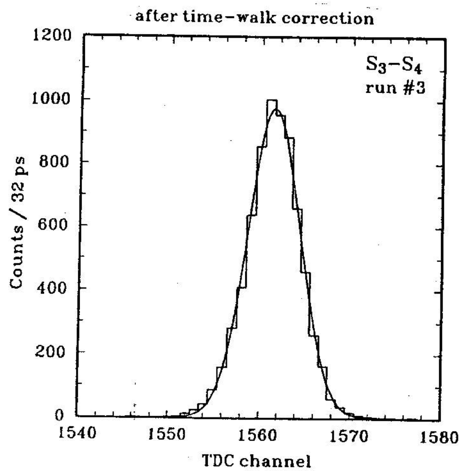


Fig.4. Time-of-flight $\mathcal{T}_{S_3-S_4}$ spectrum after the time-walk correction. The solid curve is a Gaussian fit with $\sigma = 91$ ps. Corresponding time resolutions of $S_3$ and $S_4$ counters are $\sigma_3 = 74 \pm 9$ ps and $\sigma_4 = 58 \pm 10$ ps.

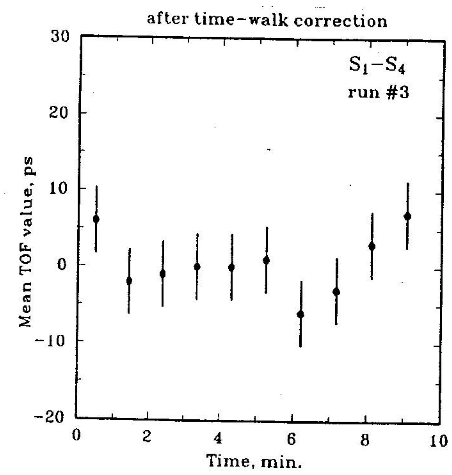


Fig. 5. Typical drift of the mean $\mathcal{T}_{S_1-S_4}$ value during the run.

resolutions obtained by the described before procedure are presented in Table 2. We note that the time resolutions are similar to the measured before.

## 5. Conclusions

We tested the set of four scintillation TOF counters 6.0 cm long, 2.4 cm wide, and 2.4 cm thick during a long-term run on the particle beam. The average time resolution ($\sigma$) of about 70 ps is estimated for the whole test. This value includes the contribution of the TOF drift and, being corrected on the last one, the time resolution could be improved for up to (10-15)%.

The reproducibility of the timing results was tested and it was appeared to be rather satisfactory.

Finally, in this work we have achieved the timing accuracy required by the planned experiment to have a good separation of pions, kaons, and protons.

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