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MEASUREMENT OF THE NEW **HAMAMATSU** PHOTOMULTIPLIER CHARACTERISTICS AND THE SCINTILLATOR'S DECAY TIME

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P. Salin[1] and S. Sukhotin[2]

Abstract

This work was done in the framework of the future CHOOZ experiment to search for neutrino oscillation at a distance of 1 km from a nuclear reactor.The proposal of the CHOOZ experiment rests on using a large liquid scintillator detector in the center part of which gadolinium-loaded scintillator will be used.

Keywords : Photomultipliers, Photoelectron counting, Neutrinos.

Résumé

Ce travail a été fait dans le cadre de la future expérience CHOOZ qui recherche les oscillations du neutrino à 1 km de distance du réacteur nucléaire. La proposition d'expérience est basée sur l'utillisation d'un grand détecteur rempli de scintillateur liquide dont la partie centrale contient un liquide scintillant doppé au Gadolinium.

Mots-clés : Photomultiplicateurs, Comptage de photoélectrons, Neutrinos.

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Measurement of the new HAMAMATSU photomultiplier characteristics and the scintillator's decay time.

1. Introduction.

This short paper is a continuation of article[1] . Here we present the results of the measurements on a new photomultiplier (PM) as well as the time decay constants for some scintillators.

The proposal of the CHOOZ experiment rests on using a large liquid scintillator detector, the center part of which is loaded with gadolinium. Antineutrinos from nuclear reactors will be detected via the reaction :

$$\bar{\nu}_e + p \rightarrow e^+ + n$$
$$\llcorner + Gd \rightarrow \gamma_1 , \gamma_2 \ldots + \langle E \rangle = 8 \text{ MeV}$$

with a neutron lifetime in the gadolinium scintillator of about 28 μs.

The fiducial volume is viewed by 160 PM which give the information about the energy of e^+ and n events as well as the time delay between these two. The time and energy balance information will provide a localisation of an event.

Monte-Carlo calculations of efficiency and light collection parameters of the detector showed that we have for the $e^{\pm}$ 150 photo-electrons/event at E≈ 1 MeV. It means that individual PMs will basically operate in single photoelectron regime. So, the PM parameters in this regime are very important and the Chooz collaboration needs to find good PM with best peak-to-valley ratio, low dark current counting rate etc. The Collège de France group is preparing a flash ADC electronics to sample the full PM pulse shape. The results of the present test will be a part of a full PM+FADC test to be installed in the laboratory in a near future.

2. Single photo-electron regime for a new PM : HAMAMATSU R5912.

We obtained from the HAMAMATSU society a new PM : R5912. It has the same diameter - 8", the same photocathode as the R4558, which we have been already investigated (see[1]). The differences between these two PM are: the new PM (R5912) has one more dynode and a different position of the first dynode. For the R4558 model the first dynode is placed after the focusing system, while in the new one it is installed before. The dynode structures for both PM are shown on figures 1 and 2.

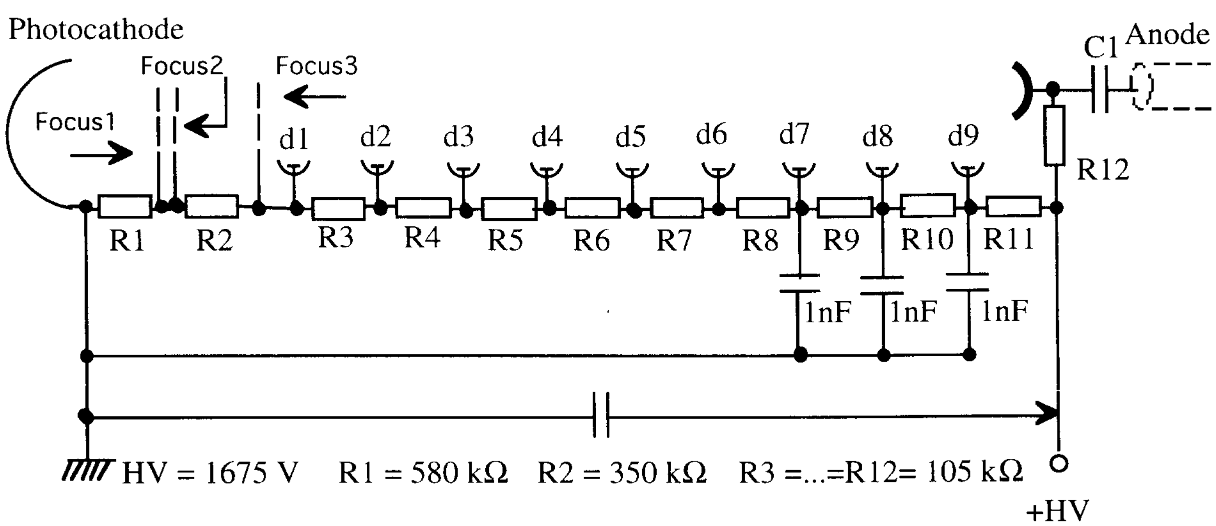

Figure 1. High voltage divider and dynode structure of HAMAMATSU - R4558.

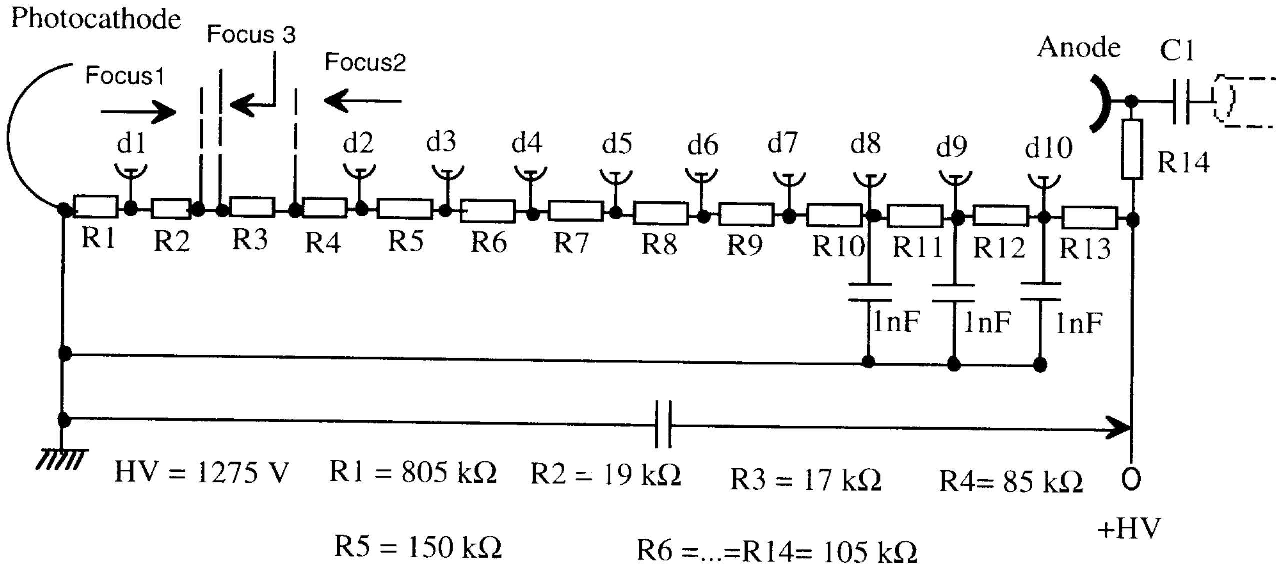

Figure 2. High voltage divider and dynode structure of HAMAMATSU - R5912.

For both models we used the dividers recommended by the HAMAMATSU society with a high voltage supplied as follows: the photocathode was grounded and the output signal was taken through a high voltage capacitor (C1 on figures 1 and 2).

3. Dark current spectrum for R5912.

The dark current amplitude spectrum for R5912 is shown on figure 3. One can compare this spectrum with the corresponding spectra for HAMAMATSU R4558 and EMI - 9351. The parameter peak-to-valley ratio is much better for the new model than for R5446 and practically the same as for EMI.

We investigated the single photo-electron regime of R5912 with a LED (light emitting diode) in an avalanche mode. The results of charge and transit time measurements are presented on figures 4 and 5 respectively.

The ADC distribution was fitted. The single photo-electron peak can be described by a gaussian (parameters P3,P4 and P5 on figure 4). The pedestal is in channel 23. The following expression: $((\text{mean peak position - pedestal})/\text{width})^2$, which corresponds to the first dynode gain coefficient, is bigger than for EMI.

As for the transit time distribution (figure 5), one can see a rather complicated structure. We divided this distribution in three time windows, which are marked by vertical arrows on figure 5: the prepulses, the main peak and the afterpulses.

A four gaussian fit was done to describe the prepulses and the main peak. The obtained parameters are presented on figure 5 with a fitted curve and the individuel gaussians. The parameters P2, P5, P8 and P11 are the mean peak position for each gaussian; P3, P6, P9, P12 are the corresponding widths (sigma). If this kind of fit is correct, one can calculate a mean delay time between the prepulses and the main peak. The prepulses are located at 5.8 ns and 9.6 ns before the main peak and their amount is about 5% .

We made an analys is to find what ADC distribution corresponds to each of these three time windows. The result is shown on figure 6, with:

- plot A - for all three windows (grand total);
- plot B - for the prepulses window;
- plot C - for the main peak window;
- plot D - for the afterpulses window.

Comparing the transit time measurements for HAMAMATSU R5912 and EMI - 9351, we can make the following conclusions:

1. both PMs have a good time jitter for main peak (about 1 ns);
2. both PMs have the same amount of the afterpulses;
3. R5912 has more prepulses (about 5%) than EMI (< 1%).

For some kind of experiments this last item may be a disadvantage of R5912.

4. Decay time of the scintillators.

In the article[1] we gave the results of the decay time measurements for the scintillators wich we are going to use in CHOOZ experiment. We also have done the same measurements for three types of Nuclear Enterprise scintillators: NE224, NE235C and NE235H. We used, of course, the same PMs (EMI and XP 2020) and the same electronics. For all of these scintillators a fit with three exponentials, one gaussian (to describe the afterpulses) and a constant (accidental coincidences) was done. The resulting plots with the fitted parameters are shown on figures 7, 8, 9, 10 and 11 for the gadolinium-free, gadolinium-loaded CHOOZ scintillators, NE235C, NE235H anf NE224 respectively. For the sake of convenience, the resuts of all mesurements are brought together in Table 1, where τ_i is the decay time in ns and Y_i is the corresponding yield in %.

Table 1.

Decay time parameters Scintillator type.	τ_1 [ns]	Y_1 [%]	τ_2 [ns]	Y_2 [%]	τ_3 [ns]	Y_3 [%]
Gadolinium-free	**7.3 ± 0.4**	70 ± 4	**31.7 ± 1.6**	28 ± 1	**93.6 ± 4.7**	2.0 ± 0.1
Gadolinium-loaded	**4.0 ± 0.2**	72 ± 4	**24.2 ± 1.2**	26 ± 1	**96.0 ± 4.8**	2.0 ± 0.1
NE235C	**6.6 ± 0.3**	81 ± 4	**19.7 ± 1.0**	17 ± 1	**86.0 ± 4.3**	2.0 ± 0.1
NE235H	**4.5 ± 0.2**	74 ± 4	**19.2 ± 1.0**	21 ± 1	**69.0 ± 3.4**	5.0 ± 0.2
NE224	**2.3 ± 0.1**	80 ± 4	**11.3 ± 0.6**	17 ± 1	**53.5 ± 2.7**	3.0 ± 0.2

From the Nuclear Enterprise data sheet we got the fastest decay time for NE224, wich is τ_1=2.6 ns. This value is in a good agreement with our measurement.

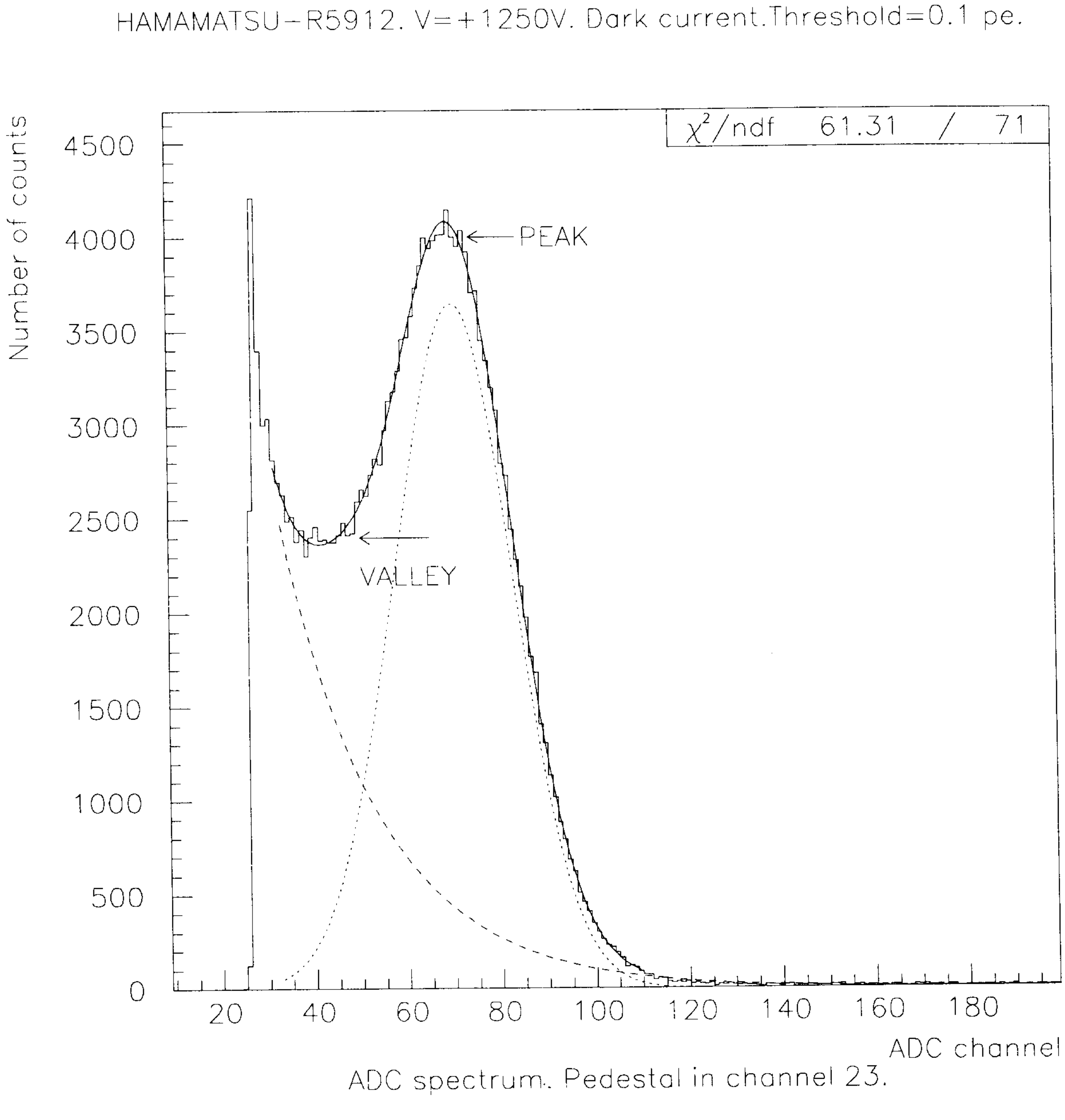

Figure 3. The dark current for R5912 PM.

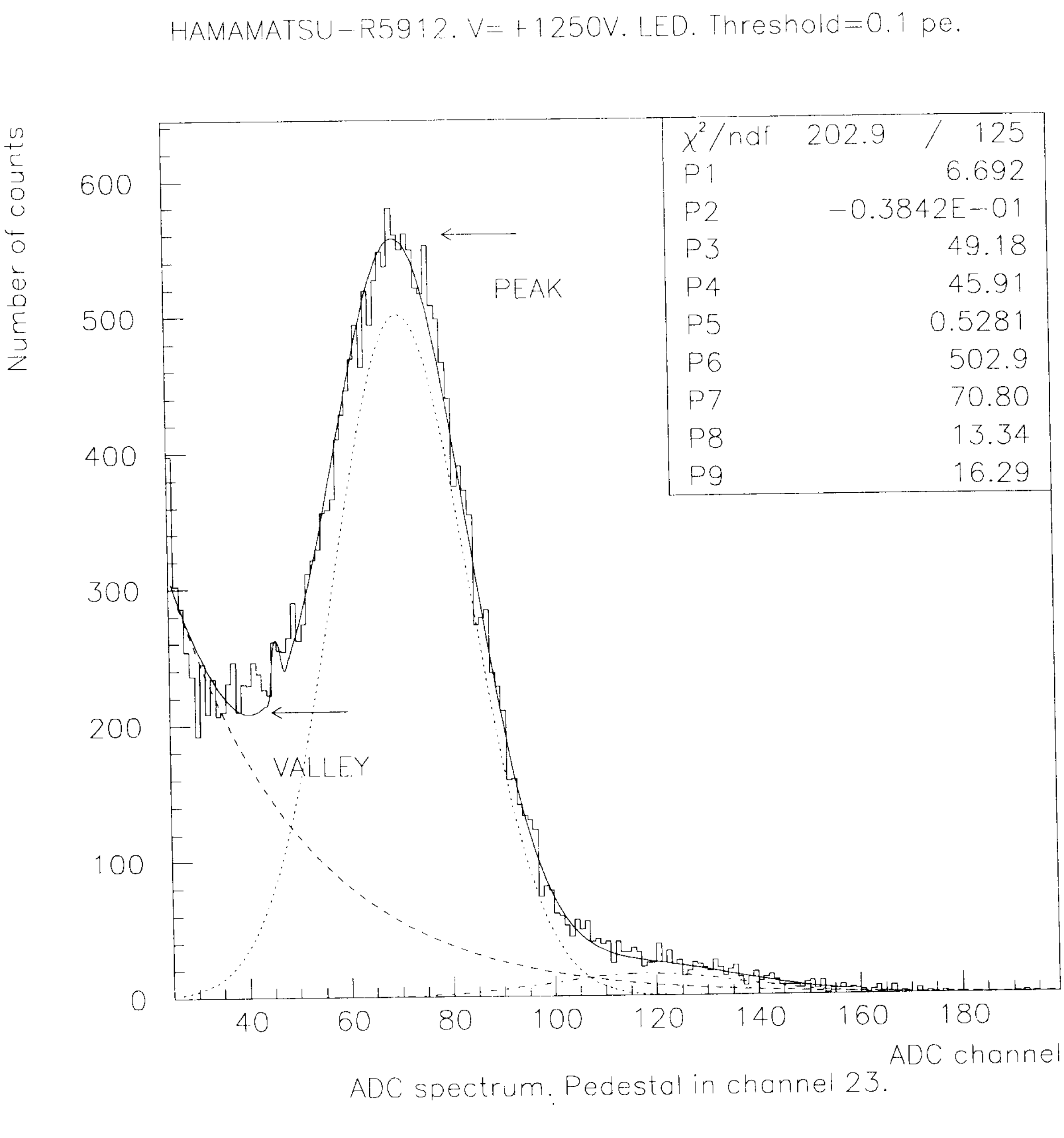

Figure 4. ADC - single photo-electron.

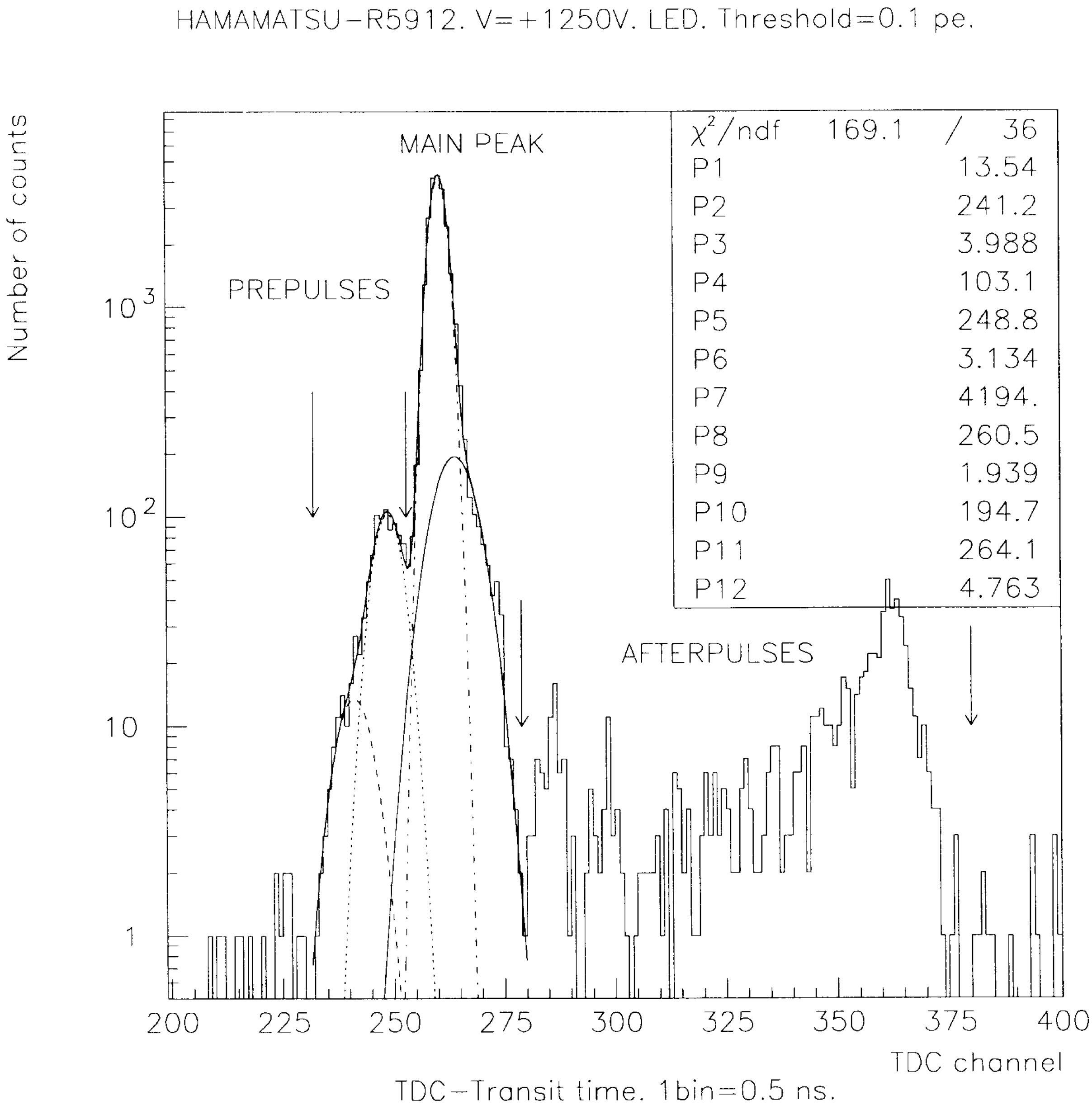

Figure 5. TDC - transit time for single photo-electron regime.

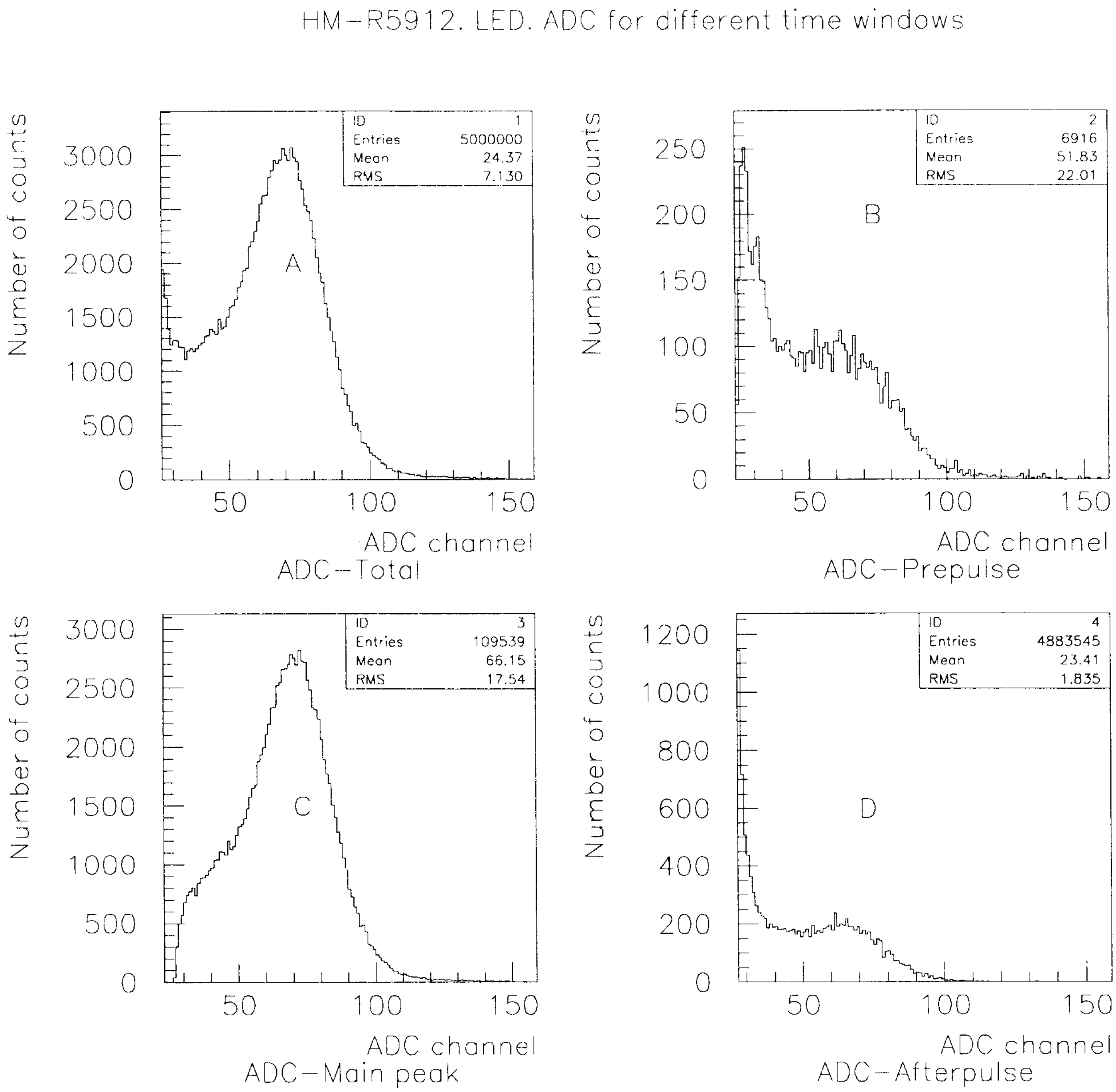

Figure 6. ADC for different time distribution windows.

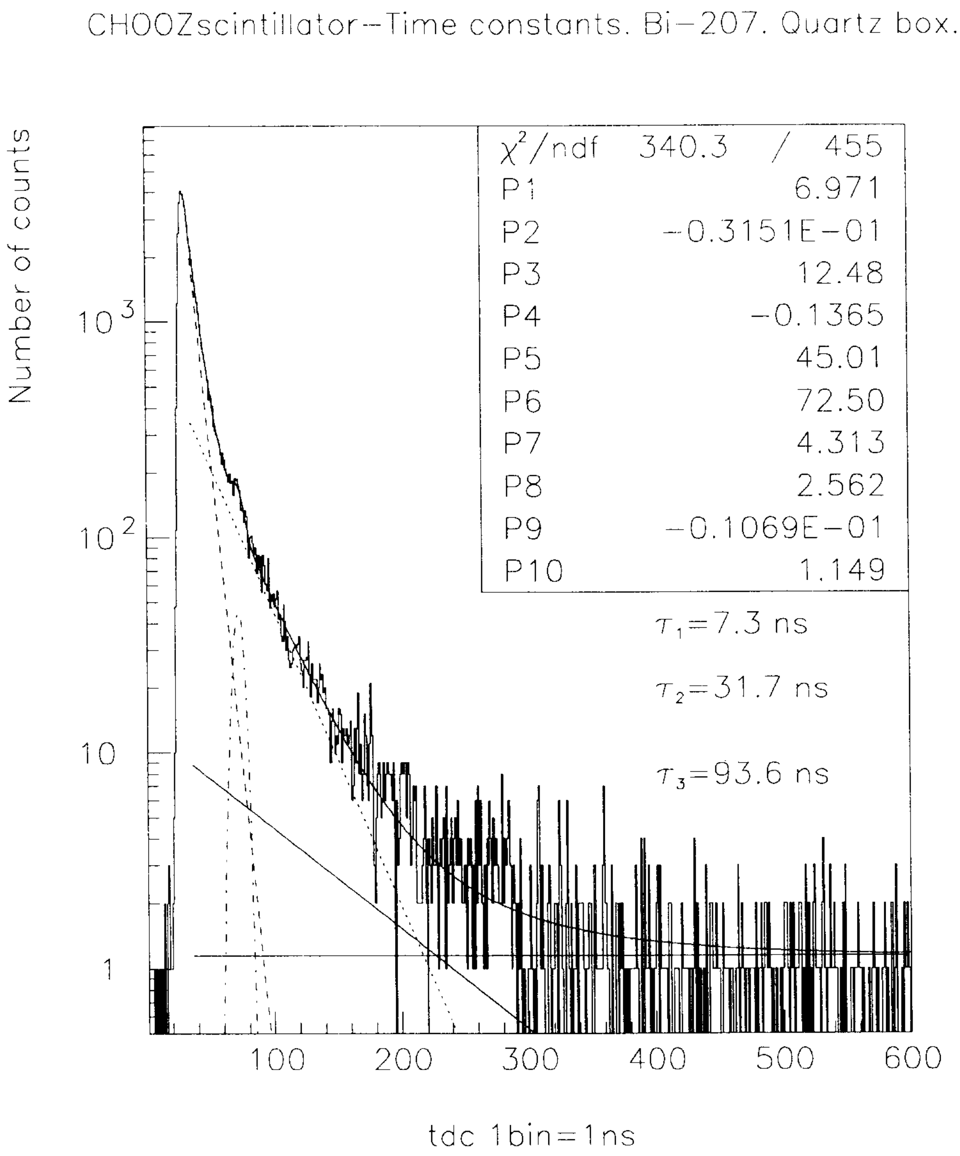

Figure 7: Time-constant measurements for the gadolinium-free scintillator.

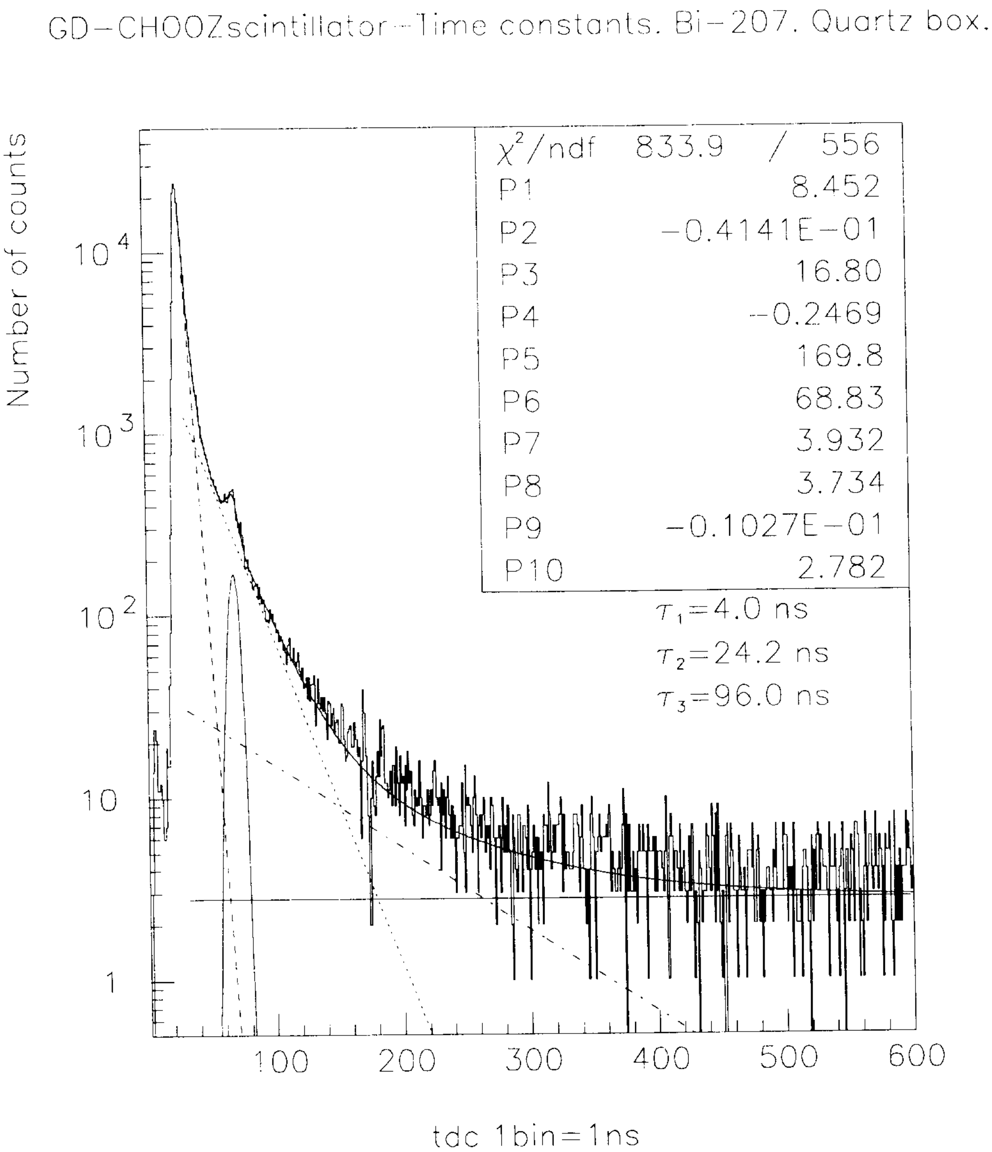

Figure 8: Time-constant measurements for the gadolinium-loaded scintillator.

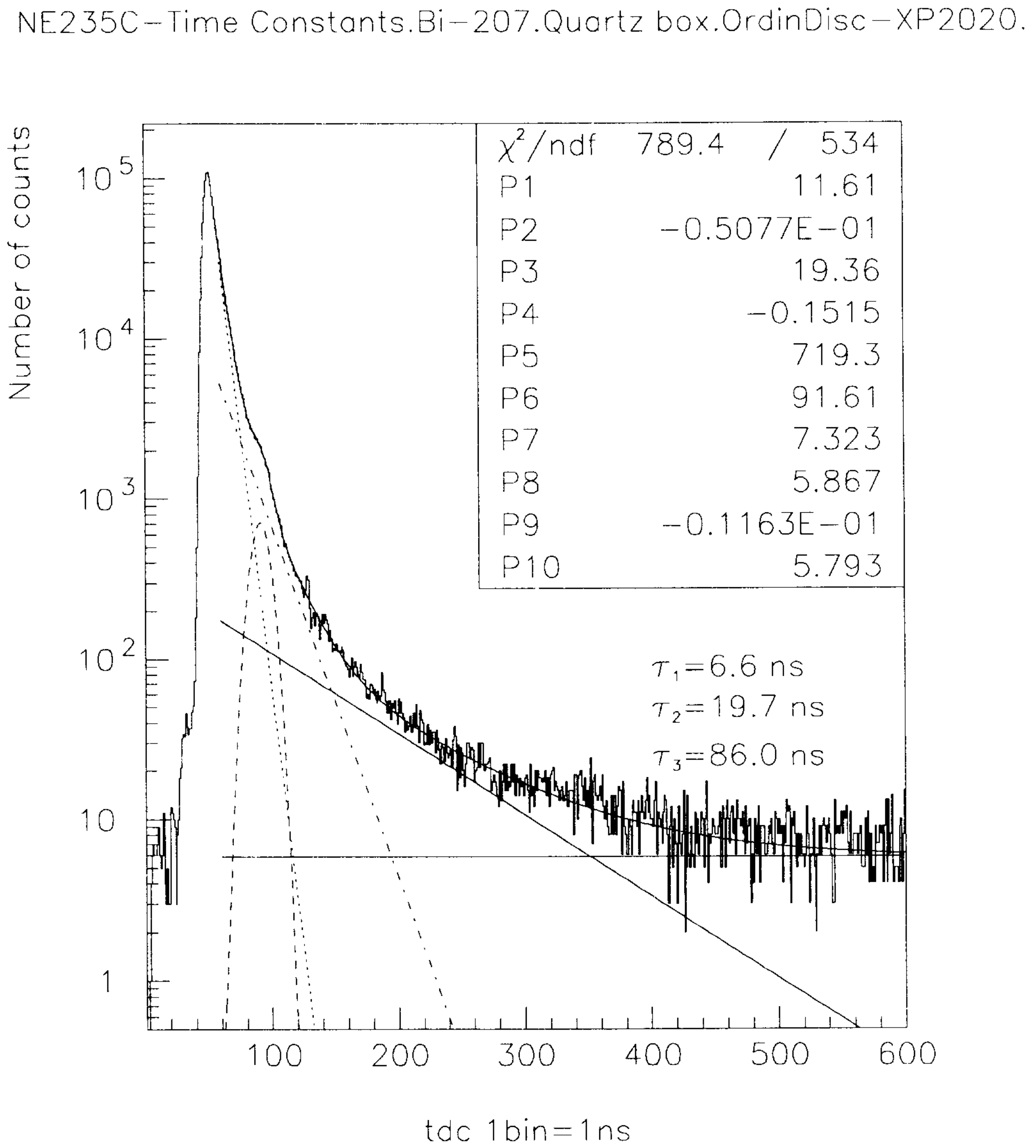

Figure 9. Time-constant measurements for NE235C scintillator.

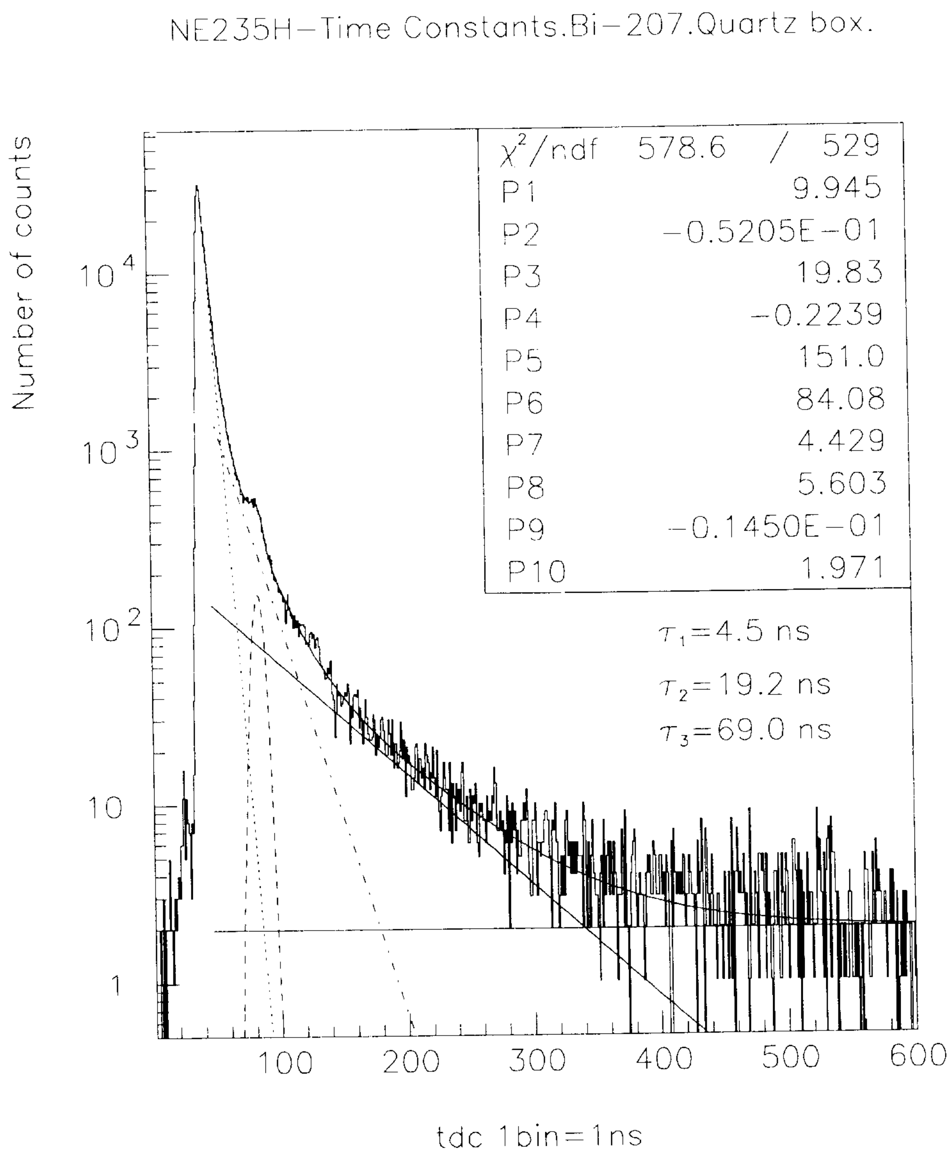

Figure 10. Time-constant measurements for NE235H scintillator.

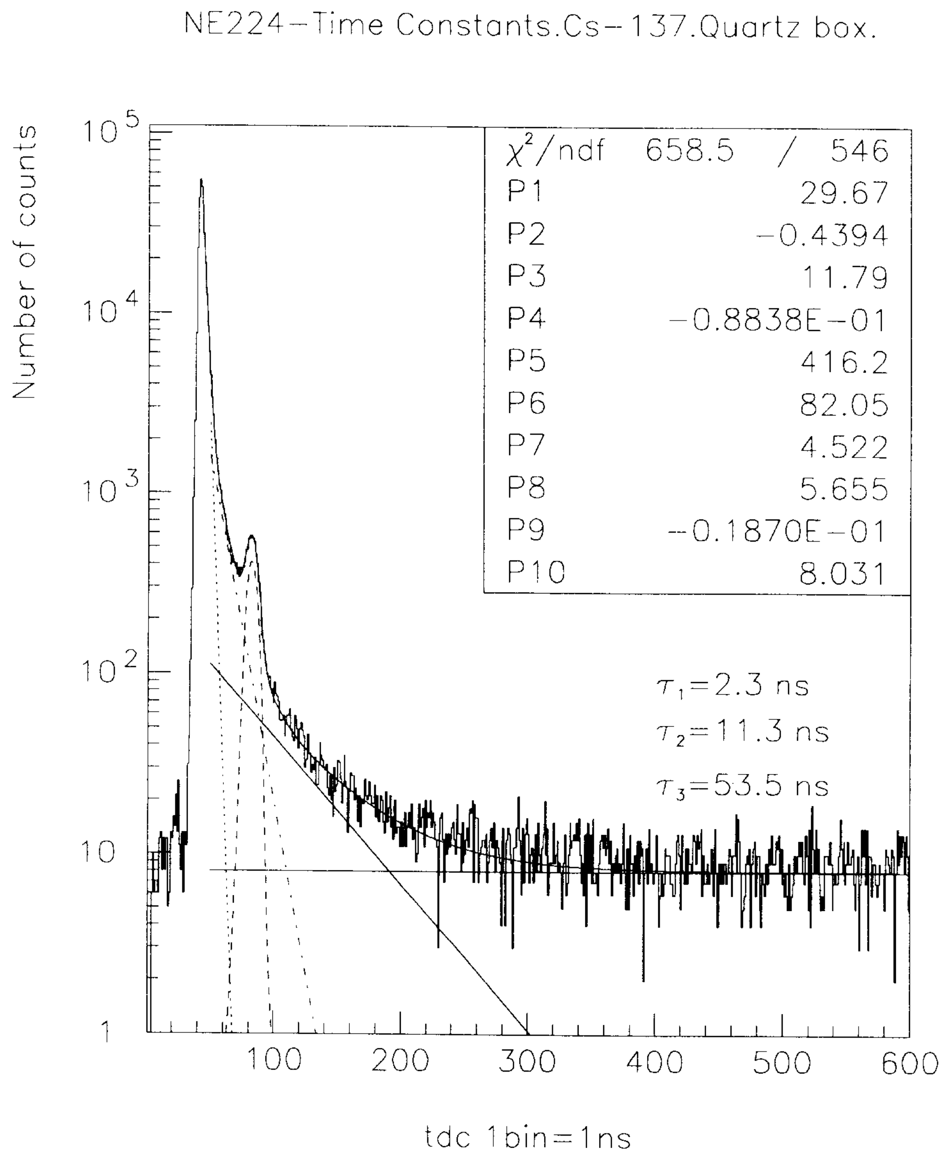

Figure 11. Time-constant measurements for NE224 scintillator.

Acknowledgement

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[1] Measurement of **EMI** and **HAMAMATSU** photomultiplier characteristics for the **CHOOZ** experiment. LPC 94 15.