Time-Walk Corrections for the CLAS TOF System

SCOTT M. KETTLER, JOHN FICENEC, AND
ELTON S. SMITH
AUGUST 16, 1996

1 INTRODUCTION

The CLAS time-of-flight (TOF) system has six sectors each with 57 scintillators (bars). Each of these scintillators is fitted with 2 photomultiplier tubes (PMTs) labelled "left" and "right." When a track deposits energy in a scintillator, the timing of the track is related not only to the flight time from the target and the position in the scintillator, but also to the rise time and pulse height from each PMT. It is inevitable that during data runs the amount of energy deposited per track will not be constant. The pulse from a scintillator hit by a track which deposits a large amount of energy will exceed the leading-edge discriminator threshold sooner, resulting in a shift in the timing of the pulse relative to tracks that deposit less energy. This shift is called time-walk. In order to establish a very precise time-of-flight, we need to correct for this shift. This paper reports on the efforts to obtain an accurate, robust algorithm for time-walk corrections.

2 BACKGROUND

The data for this study was provided by a laser pulse of varying intensity input at the center of each scintillator [1, 2]. A file was created for each bar that appeared in the original data file. Each file contains two unfit histograms (unfit means no superimposed function), two scatter plots, twelve fit histograms, and one ntuple. The ntuple has only the ADCs and TDCs of the data used in the fits for the associated scintillator. The two unfit histograms show the profiled data for each PMT, whereas the fit histograms show three different functions superimposed over the profile histogram for each PMT. Each of the functions is fit using both a chi-square (χ^2) and log-likelihood ($\mathcal{L}$) method on the individual data points to the full range of ADC values and also to the range of 0-3000 ADC counts (three full range fits and three cut range fits for each PMT). This arrangement of data allows quite a bit of versatil-

ity in what one can view in the Physics Analysis Workstation (PAW++) [3] Graphics Window. The TDC values in the ntuples are accurately scaled to nanoseconds, typically 0.045 ns/count. The histogram numbering conventions are as follows:

- left = 1, right = 2, function# = 1, 2, or 3
- unfit# = (bar# * 10) + (left or right)
- fit# = (unfit# * 10) + function# - 1 (+ 3 when fitting the cut ADC range)
- scatterplot# = unfit# + 2
- ntuple# = 2000 for all bars

The parameters of the functions and their errors have been saved in text files for further analysis.

3 RESULTS

The fit parameters from function1 [1] (Equation (1)) are shown in Figure 1. The ADC range used in these fits is 0-3000, this is below the point at which PMT saturation effects become significant:

$$Function1 = P1 + \frac{P2}{ADC^{P3}} \tag{1}$$

where *P1*, *P2*, and *P3* are the fit parameters. Figure 2b shows the resulting fit for the left PMT of bar number 8. An adjusted fit was made in order to correct for PMT saturation (Equation (2)). Figure 3 shows this adjusted fit when applied to bar 8. The fits were matched at 2500 ADC counts.

$$Fit = Function - PAR1(ADC - ADC_o)^{PAR2} \tag{2}$$

where *Function* is the original function (1, 2, or 3) fit up to ADC_o, the point at which the fit changes (2500 counts). *PAR1* & *PAR2* are the parameters of the adjusted fit determined for the interval above ADC_o. The fit function has a continuous value and derivative at ADC_o due to the constraint *PAR2* > 1. For bar 8, *PAR1* and *PAR2* are 11.0×10^{-5}/1.11 and 9.9×10^{-5}/1.08 for left and right PMTs respectively, which is typical for most bars measured. Two other functional forms, given by Equations (3) and (4), provide fits to the data of comparable quality to the first fit (see Figures 2c and 2d).

$$Function2 = P1 + P2\log(ADC) + P3(\log(ADC))^2 \tag{3}$$

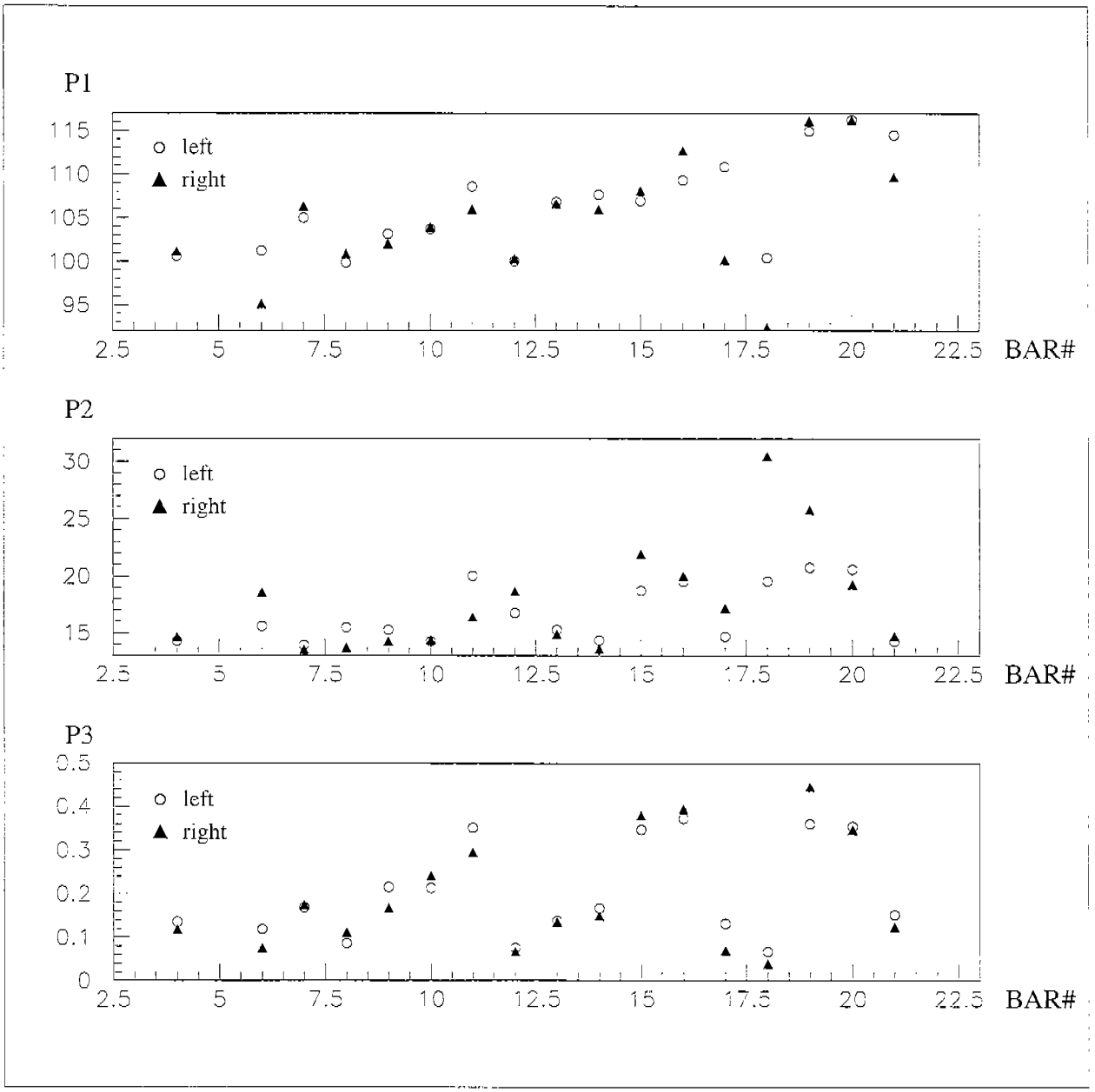

Figure 1.: Parameters for Equation (1) per scintillator (bar).

$$Function3 = P1 + P2\log(ADC) + \frac{P3}{\sqrt{ADC}} \tag{4}$$

where, again, *P1*, *P2*, and *P3* are the fit parameters. The resulting parameters are displayed in Figures 4 and 5 respectively. Two additional functions, each with only two parameters, $P1 + P2/\sqrt{ADC}$ and $P1 + P2/\log(ADC)$, gave fits with chi-squares that are typically 25% to 150% larger than the chi-squares for the first three functional fits.

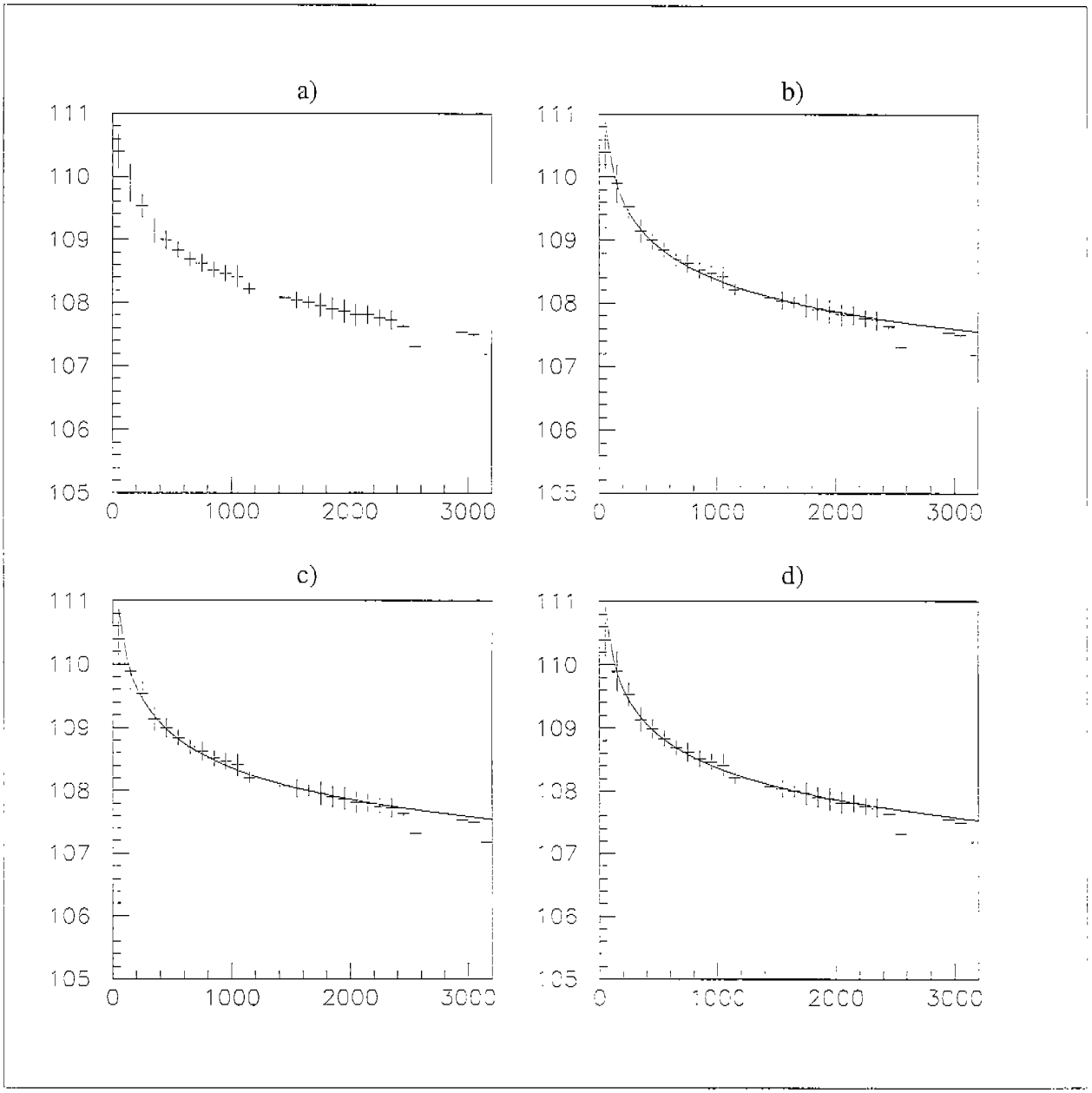

Figure 2.: Fits for bar 8 using the cut ADC range a) unfit profile b) profile with function1 superimposed c) profile with function2 d) profile with function3

Since each of the functions is fit using both a chi-square and log-likelihood method, the two methods can be compared. The log-likelihood method does not significantly change the parameters of any fit when compared with the chi-squared method. In fact, the parameters of the log-likelihood fits are within the errors on the parameters of the chi-squared fits. As an example, Table 1 lists the values of the parameters and their errors from the MINUIT [3] fitting package for the various functions and fitting methods on bar 8 below $ADC_o = 3000$.

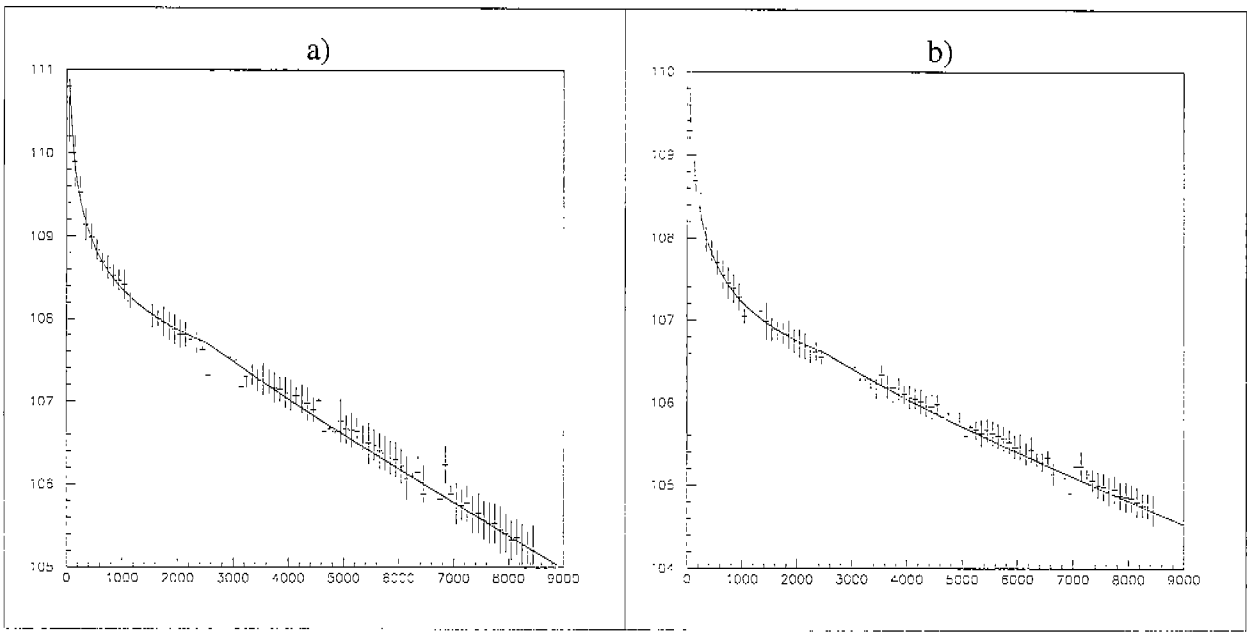

Figure 3.: Adjusted fit as in Equation (2) for bar 8 a) left PMT b) right PMT

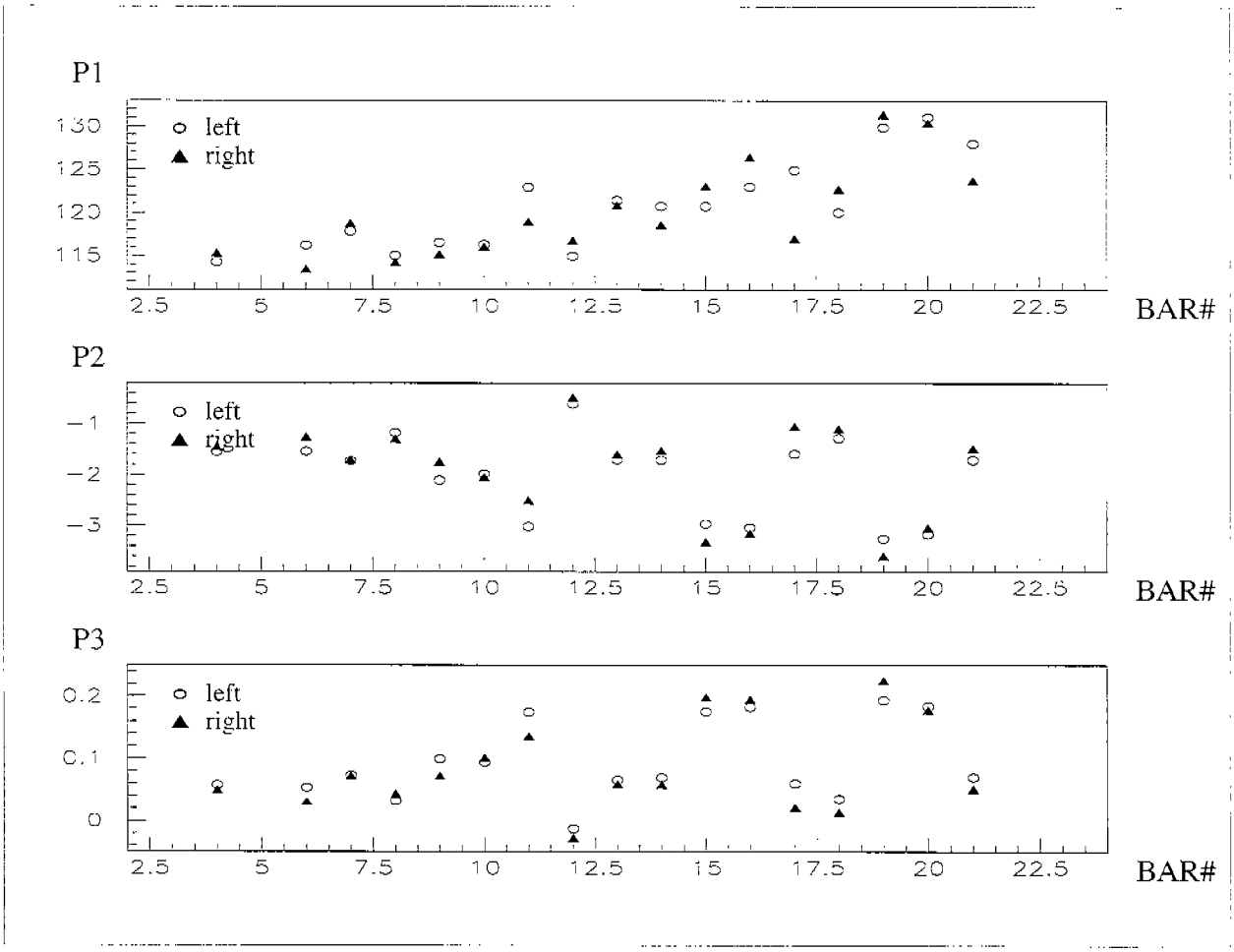

Figure 4.: Fit parameters for Function2

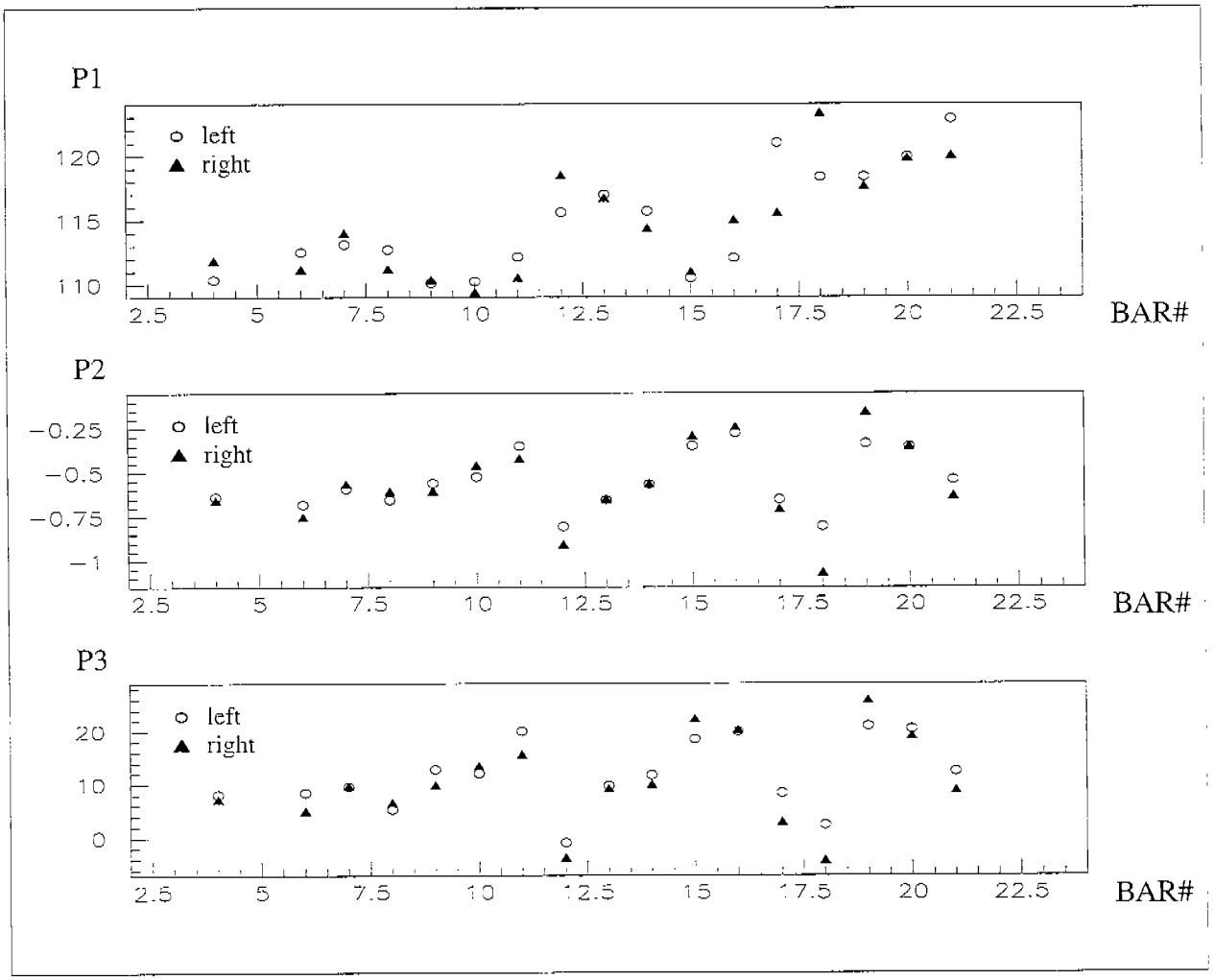

Figure 5.: Fit Parameters for Function3

	Function1	**Function1**	**Function2**	**Function2**	**Function3**	**Function3**
	χ^2	$\mathcal{L}$	χ^2	$\mathcal{L}$	χ^2	$\mathcal{L}$
P1 left	99.86 ± .06	99.85 ± .06	114.98 ± .03	114.98 ± .03	112.72 ± .06	112.72 ± .06
P2 left	15.463 ± .062	15.465 ± .062	-1.175 ± .010	-1.173 ± .010	-0.655 ± .007	-0.654 ± .007
P3 left	0.087 ± .001	0.086 ± .001	0.031 ± .001	0.031 ± .001	5.296 ± .282	5.309 ± .282
χ^2/DoF	0.75	0.75	0.75	0.75	0.74	0.74
P1 right	100.87 ± .06	100.87 ± .06	114.16 ± .03	114.15 ± .03	111.22 ± .07	111.22 ± .06
P2 right	13.711 ± .058	13.712 ± .070	-1.298 ± .010	-1.297 ± .010	-0.607 ± .009	-0.608 ± .007
P3 right	0.111 ± .001	0.111 ± .001	0.043 ± .001	0.043 ± .001	6.594 ± .314	6.580 ± .275
χ^2/DoF	0.95	0.95	0.95	0.95	0.95	0.95

TABLE 1. : Bar 8 fit parameters and errors for chi-squared and log-likelihood methods using Functions 1, 2, & 3.

CONCLUSIONS

We have investigated the time-walk effects in 17 scintillators of different lengths each with two PMTs. For ADC values below PMT saturation at least three functions, each with three parameters, give an accurate description of these effects. Above PMT saturation an additional two parameters are required to describe the phenomenon. The final choice of functional form will be guided by the behavior of the fit parameters that are monotonic as the bar length changes and also by consistency between PMTs on the same bar and between bars of equal length in the six sectors of the CLAS detector.

REFERENCES

[1] M. Guidal *et. al.*, "Laser & Cosmic-Ray Calibration of the CLAS TOF System," CLAS-NOTE-96-004, March 19, 1996.

[2] Chris Taggart, "Developmental Testing of a Laser Calibration System for the CLAS TOF Scintillation Counters," CLAS-NOTE-95-010, June 29, 1995.

[3] CN/ASD Group. *PAW Users Guide*, Program Library Q121. CERN, October 1993; *MINUIT-Users Guide*, Program Library D506. CERN, 1993.