Position Resolution - Update 3

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Data from May 31, 2024

In this document we examine scintillator 1-4 with paddle CD on top. Paddles are arranged parallel to each other with one on top of the other and board 1 above 8, and 2 above 7. The Sr-90 source was varied along the length of the paddle, centered along the width of the scintillator bar of interest. This report provides data for this scintillator with better matched gains than what was provided in the first installment of this series.

1 Position Relationships

Table 1: Time difference of absolute time and the average time across the scintillator in coincidence fit parameters, for boards 1, 4, 5, and 8 with the source directly over scintillator 1-4.

		t1 - (t5+t8)/2		t4 - (t5+t8)/2		t5 - (t1+t4)/2		t8 - (t1+t4)/2	
Run	Position (cm)	Centroid (ns)	σ (ns)	Centroid (ns)	σ (ns)	Centroid (ns)	σ (ns)	Centroid (ns)	σ (ns)
104	3	-0.817	0.267	-0.366	0.278	0.969	0.284	-0.005	0.295
105	7	-0.533	0.265	-0.33	0.282	0.55	0.299	0.09	0.305
106	11	-0.046	0.276	-0.431	0.276	0.072	0.301	0.18	0.303
108	15	0.222	0.276	-0.994	0.268	-0.084	0.296	0.633	0.293

Table 2: Width plot fit parameters for boards 1, 4, 5, and 8 with the source directly over scintillator 1-4.

		w1		w4		w5		w8	
Run	Position (cm)	Centroid (ns)	σ (ns)	Centroid (ns)	σ (ns)	Centroid (ns)	σ (ns)	Centroid (ns)	σ (ns)
104	3	40.647	6.791	38.285	7.062	48	6.918	51.4	6.412
105	7	39.425	6.833	38.907	7.078	48.784	7.367	50.393	6.121
106	11	38.081	7.109	40.033	7.418	48.986	7.29	49.473	5.967
108	15	37.232	7.037	41.76	6.572	49.631	6.252	47.827	6.55

Table 3: Time difference of along a scintillator with and without a coincidence condition (time walk corrected) fit parameters for boards 1, 4, 5, and 8 with the source directly over scintillator 1-4.

		t14 twc		t14 1458 twc		t58 twc		t58 1458 twc	
Run	Position (cm)	Centroid (ns)	σ (ns)	Centroid (ns)	σ (ns)	Centroid (ns)	σ (ns)	Centroid (ns)	σ (ns)
104	3	0.424	0.325	0.409	0.300	-1.01	0.414	-1.035	0.365
105	7	0.155	0.324	0.157	0.299	-0.505	0.465	-0.512	0.400
106	11	-0.439	0.325	-0.435	0.297	0.046	0.477	0.066	0.401
108	15	-1.283	0.322	-1.270	0.298	0.640	0.456	0.676	0.384

Table 4: Fit parameters for plots of time difference of along a scintillator with a coincidence condition and time walk corrected when plotting with **600 bins** instead of the 200 bins used in all other plots in this report for boards 1, 4, 5, and 8 with the source directly over scintillator 1-4.

		t14 1458 twc		t58 1458 twc	
Run	Position (cm)	Centroid (ns)	sigma (ns)	Centroid (ns)	sigma (ns)
104	3	0.442	0.299	-1.003	0.363
105	7	0.190	0.297	-0.479	0.399
106	11	-0.402	0.295	0.100	0.398
108	15	-1.236	0.296	0.710	0.382

Table 5: Comparison of the fit parameters for plots of time difference along a scintillator with a coincidence condition when plotting with 200 versus 600 bins. The change in fit parameter is expressed as a percent change relative to the fit parameter found when using 200 bins.

		t14 1458 twc		t58 1458 twc	
Run	Position (cm)	Centroid (%)	sigma (%)	Centroid (%)	sigma (%)
104	3	-8.1	0.3	0.7	12.3
105	7	-21.0	0.7	5.1	14.2
106	11	7.6	0.7	-117.4	16.6
108	15	2.7	0.7	-10.9	16.2

Table 6: Fit parameter information for time difference and absolute time centroid and time difference centroid vs position plots.

	Slope (ns/cm)	Slope Uncertainty (ns/cm)	y-Intercept (ns)	y-Intercept Uncertainty (ns)
t1 - (t5+t8)/2	0.09	0.03	-1.1	0.3
t4 - (t5+t8)/2	-0.05	0.03	-0.1	0.3
t5 - (t1+t4)/2	-0.09	0.03	1.2	0.3
t8 - (t1+t4)/2	0.05	0.03	-0.2	0.3
t14 twc	-0.14	0.04	1.0	0.4
t58 twc	0.14	0.05	1.4	0.5
t14 1458 twc	-0.14	0.03	1.0	0.3
t58 1458 twc	0.14	0.04	1.5	0.4

Table 7: Fit parameter information for width centroid vs position plots.

	Slope (ns/cm)	Slope Uncertainty (ns/cm)	y-Intercept (ns)	y-Intercept Uncertainty (ns)
w1	-0.29	0.02	41.5	0.2
w4	0.29	0.04	37.1	0.4
w5	0.13	0.02	47.7	0.2
w8	-0.29	0.03	52.4	0.3

Here, we see the same behaviour in the absolute time versus source position plots as observed with scintillator 2-3 where slopes of boards attached at opposite ends of a given scintillator differ by a factor of two, yet times associated with boards at opposite positions of the overall set up (top right and bottom left board for example) match extremely well. No progress has been made in explaining this phenomenon. An interesting new feature is seen in the width vs source position plots where all widths except width 5 (w1, w4, w8) have matched slopes, with the slope of width 5 still displaying half the value of that of width 8. We have previously seen the widths being moderately well matched along a scintillator while the doubling effect was still present, but the width slope matching was not this strong and we did not previously see width slope matching between scintillators. Nevertheless, by comparing across reports it seems that how the pulse width changes has no effect on the time vs position relationships.

Plotting the fits for a given parameter over all runs again shows that the absolute times that had the greater slope on the absolute time versus position plot (t1 and t5) have more well defined separation between consecutive runs than their counterparts, as expected since a larger slope means a larger shift in the centroid from the first to the last run.

Examination of the relationship between time difference of signals seen at opposite ends of a scintillator and position again gives well matched slopes as seen in Figure 2. Perhaps this method is averaging out any defect present in the channel that produces a lower slope. However, I am still suspicious of how consistently we see the exact same form of slope mismatching and do not think this is a hardware problem by coincidence. Unless our understanding of this problem is wrong, I suspect a software issue, but I have yet to find one.

As seen in Tables 4 and 5, changing the number of bins to 600 from the standard 200 does not offer a significant benefit to the timing resolution of the system. The source position vs centroid plot looked identical to the lower plot of Figure 2 so it is excluded here.
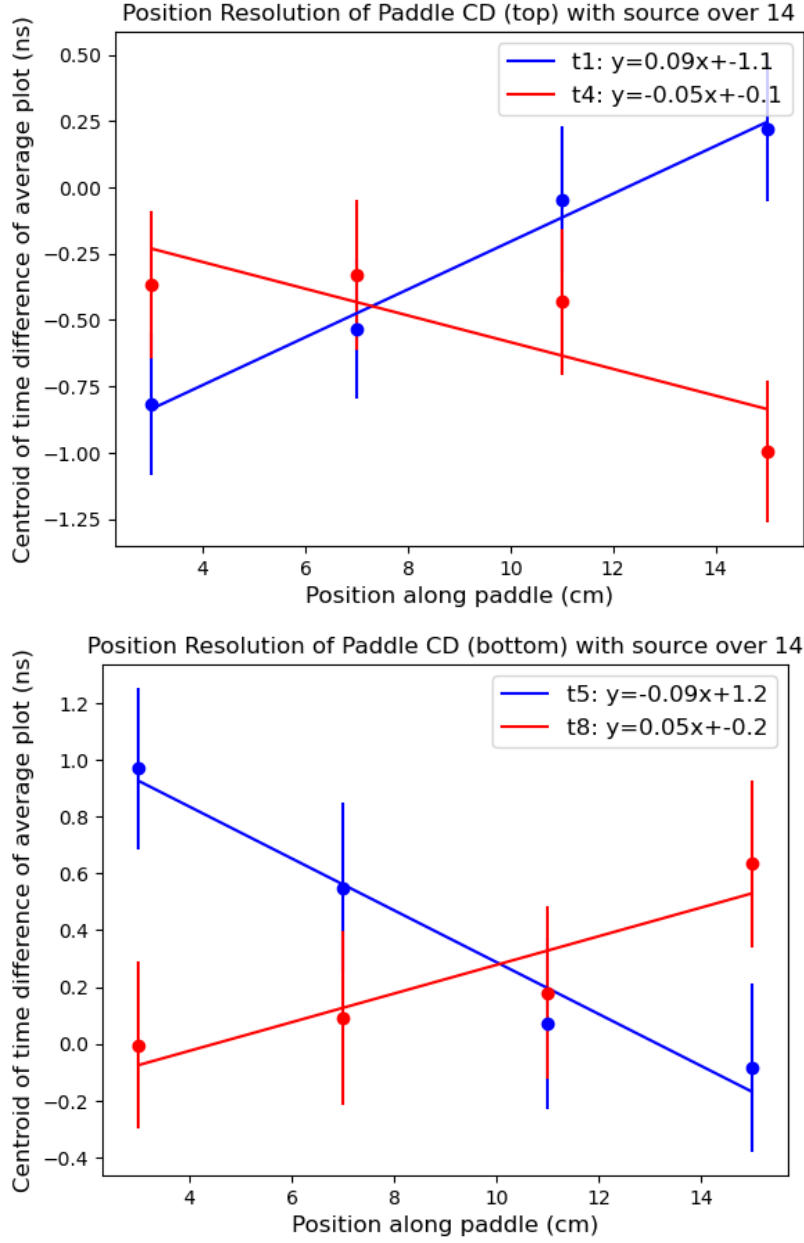
Figure 1: Absolute time vs source position for the source over scintillator 1-4, showing the data for the upper board in the top plot and the lower board in the bottom plot.
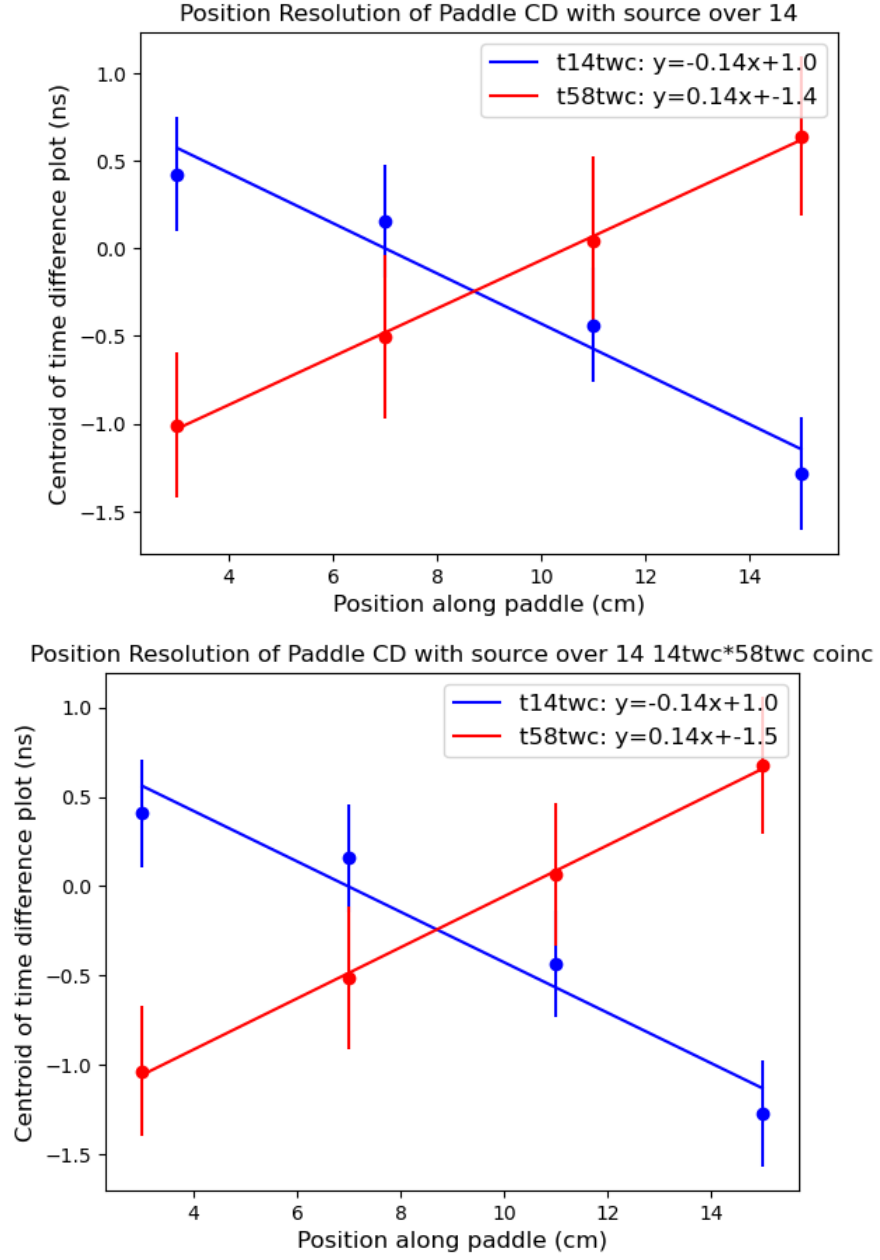
Figure 2: Time difference centroid versus source position comparing $t_4 - t_1$ and $t_8 - t_5$, time walk corrected, without (top) and with (bottom) a coincidence condition between the upper and lower paddles.
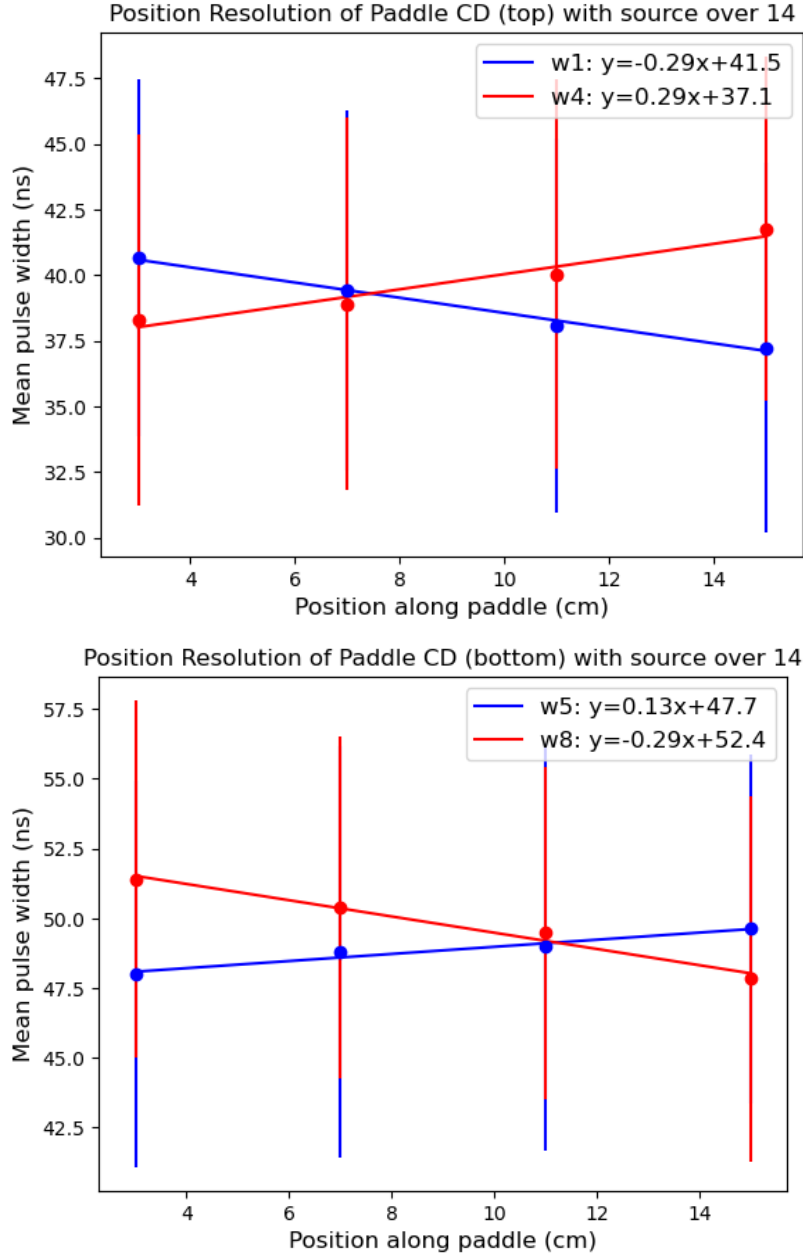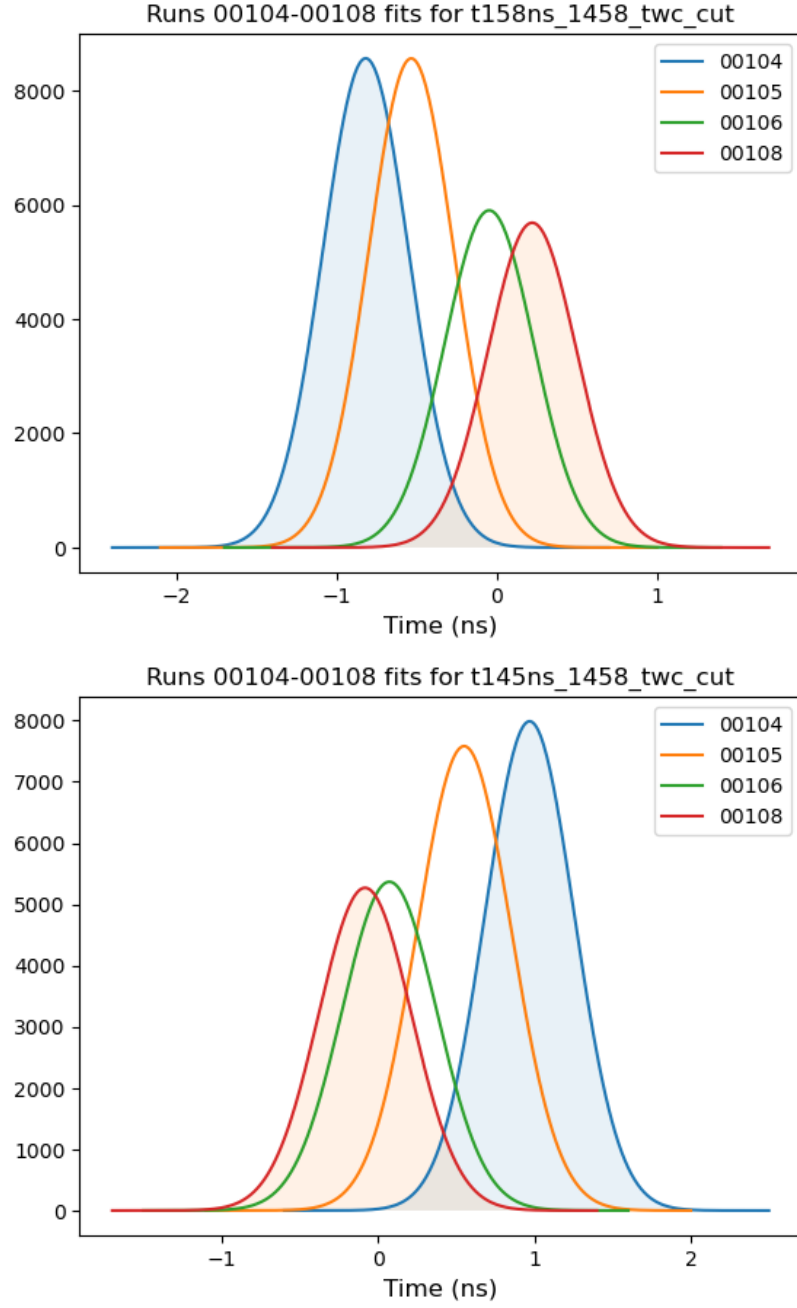
Figure 3: Pulse width vs source position for the source over scintillator 1-4, showing the data for the upper board in the top plot and the lower board in the bottom plot.

Figure 4: Fits for the plots of $t_1 - \frac{1}{2}(t_5 + t_8)$ and $t_5 - \frac{1}{2}(t_1 + t_4)$ for runs 104-108. These two absolute times had a matched slope in Figure 1 that was greater than that of the absolute time for the board opposite them along their scintillator.
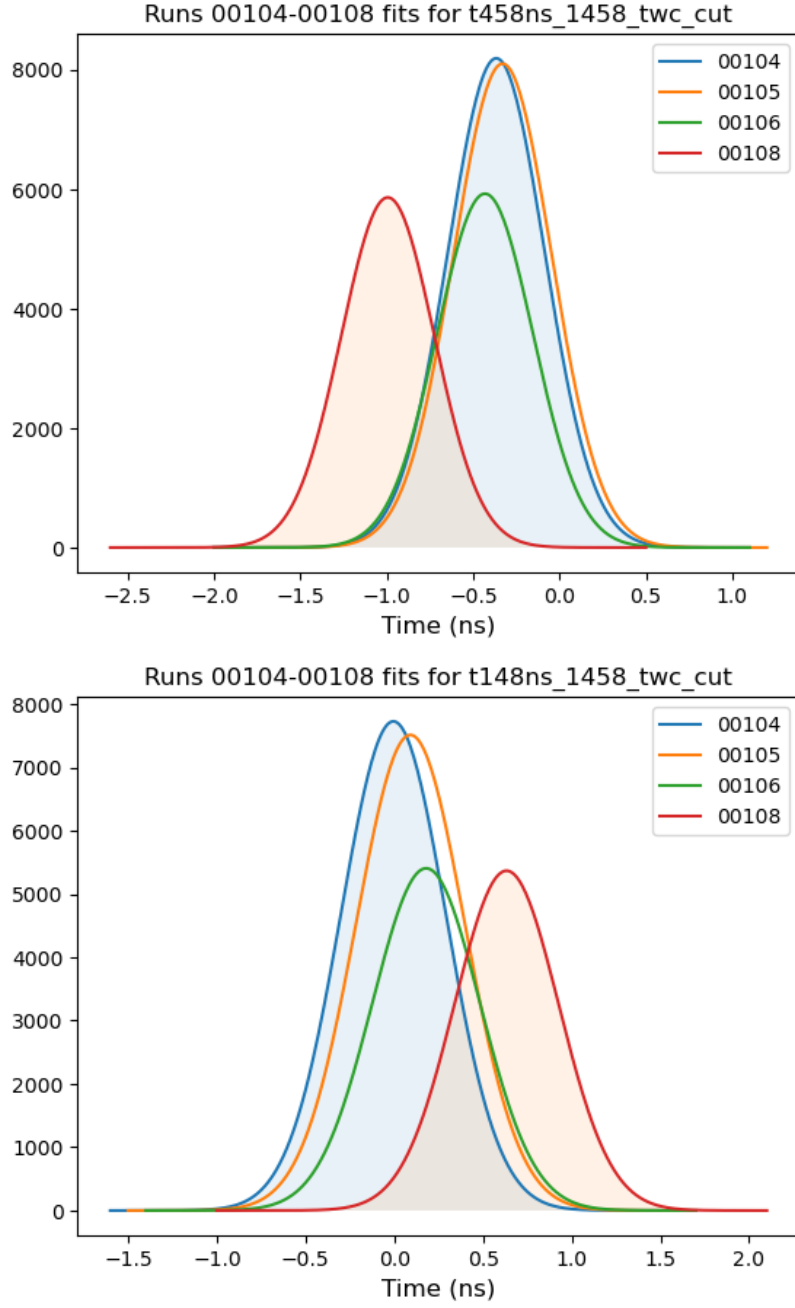
Figure 5: Fits for the plots of $t_4 - \frac{1}{2}(t_5 + t_8)$ and $t_8 - \frac{1}{2}(t_1 + t_4)$ for runs 104-108. These two absolute times had a matched slope in Figure 1 that was less than that of the absolute time for the board opposite them along their scintillator.

8
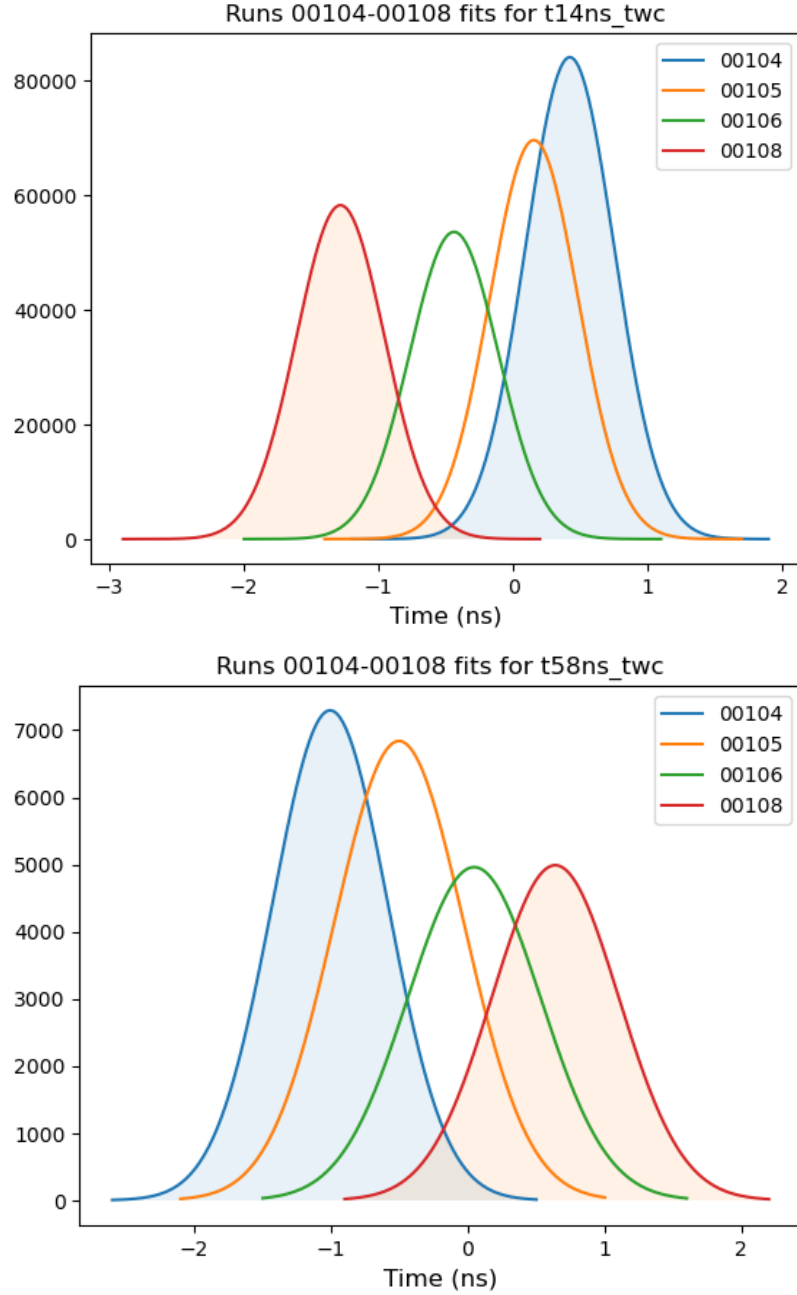
Figure 6: Fits for the plots of $t_4 - t_1$ (top) and $t_8 - t_5$ (bottom) over all source runs done for this test, time walk corrected. The first and last run are shaded in, where in run 104 the source was closest to board 1 (farthest from board 4). The coincidence condition between boards is not imposed here.
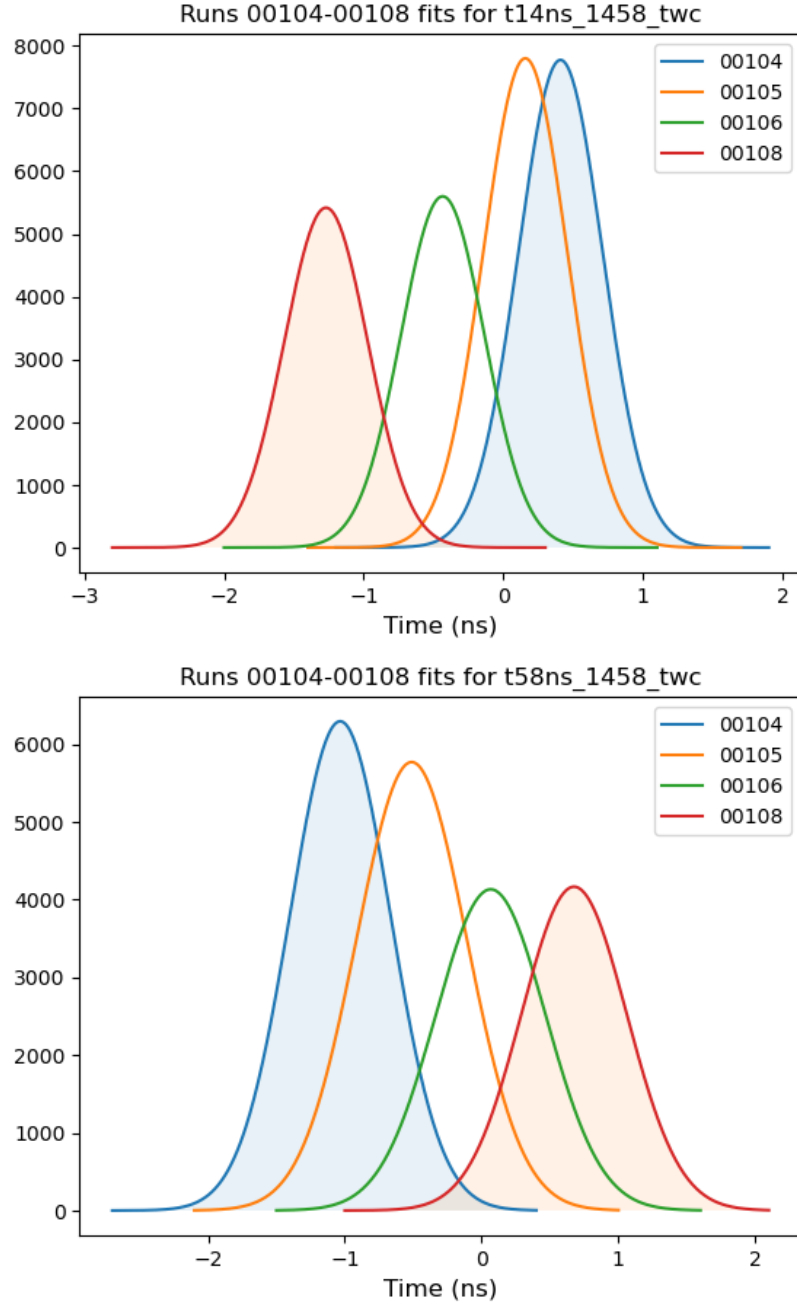
Figure 7: Fits for the plots of $t_4 - t_1$ (top) and $t_8 - t_5$ (bottom) over all source runs done for this test, time walk corrected. The first and last run are shaded in, where in run 104 the source was closest to board 1 (farthest from board 4). The coincidence condition between boards is imposed here.

2 Width Histograms
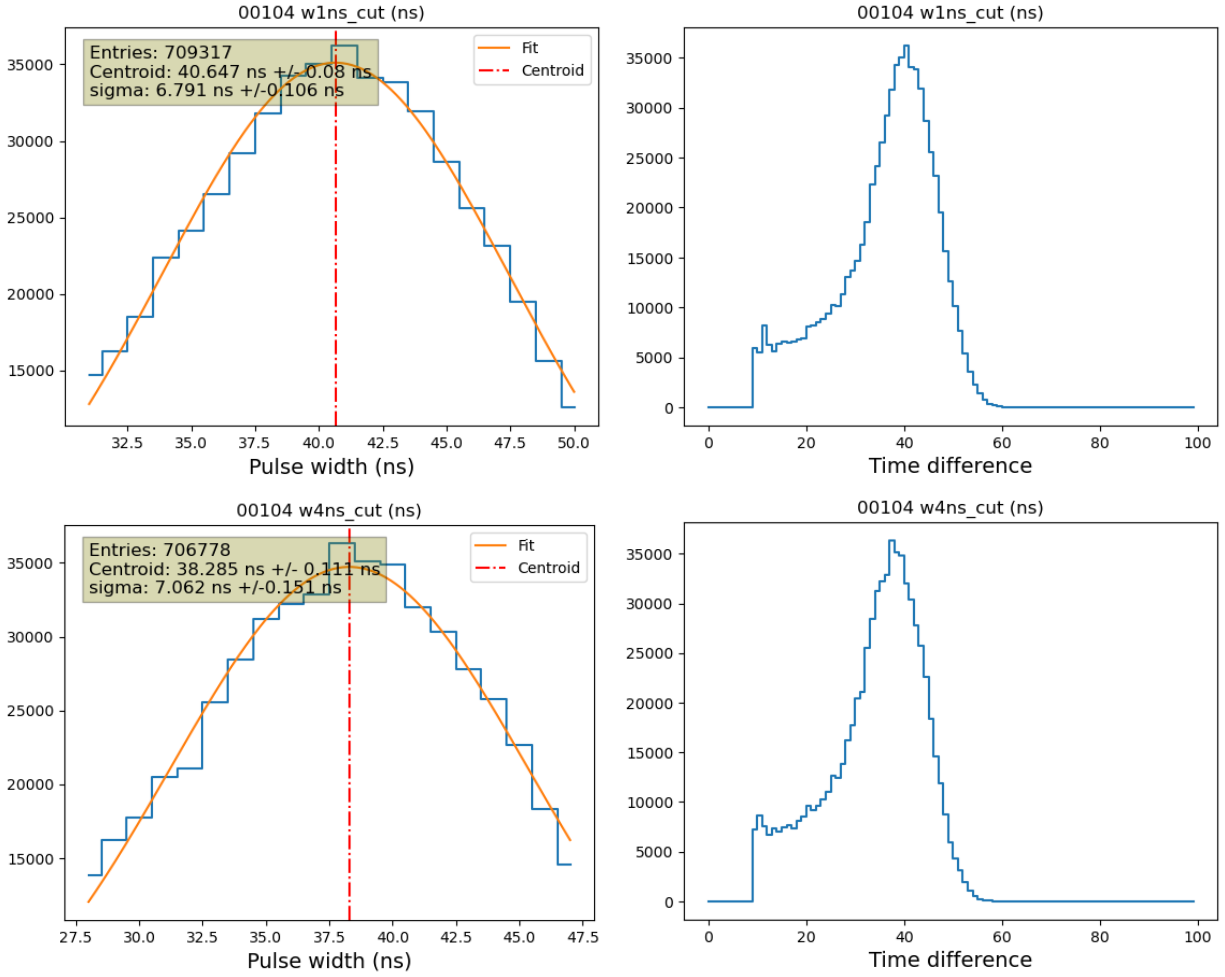
Figure 8: Pulse width histograms for w1 and w4 with the source over scintillator 1-4 for run 104.
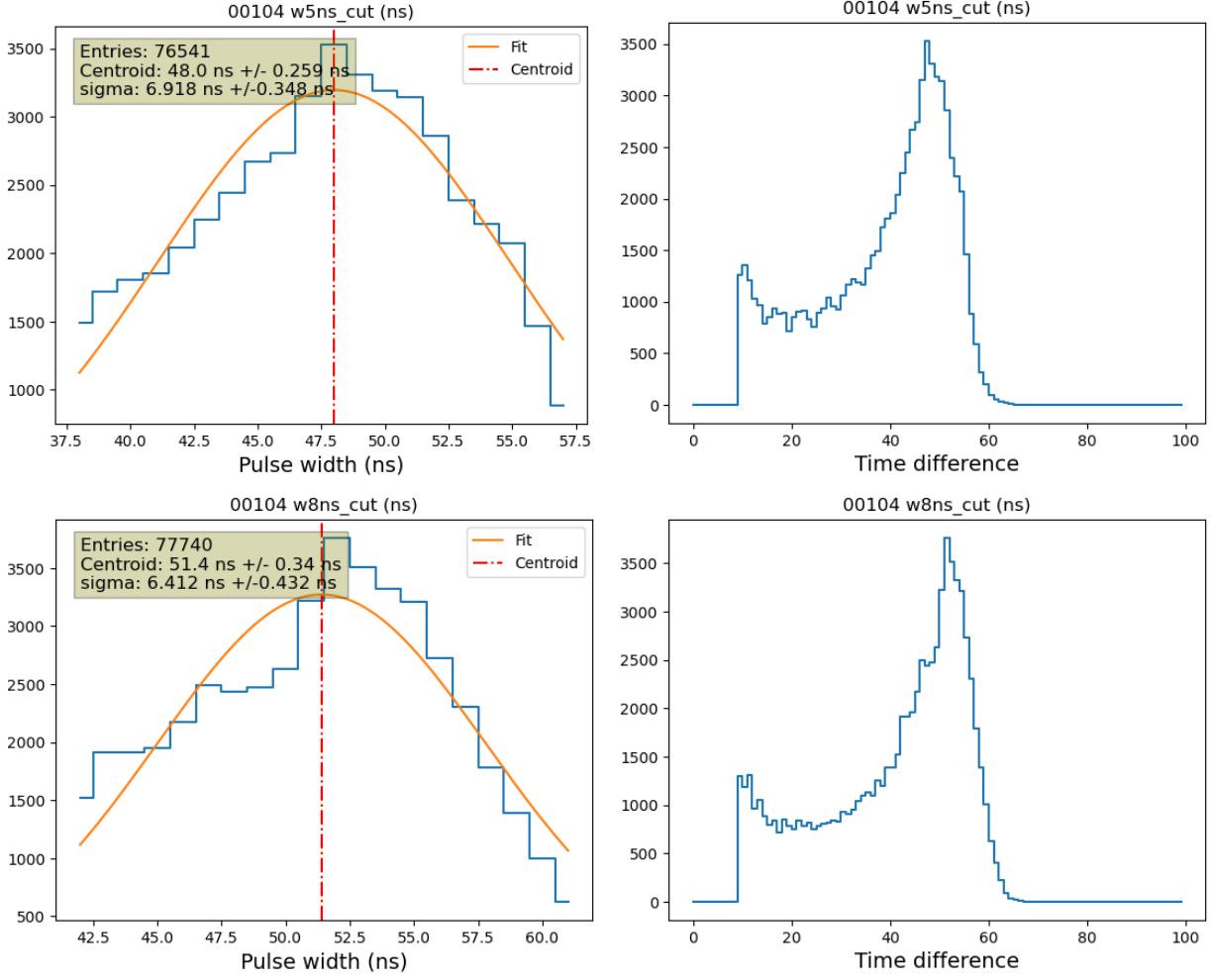
Figure 9: Pulse width histograms for w5 and w8 with the source over scintillator 1-4 for run 104.
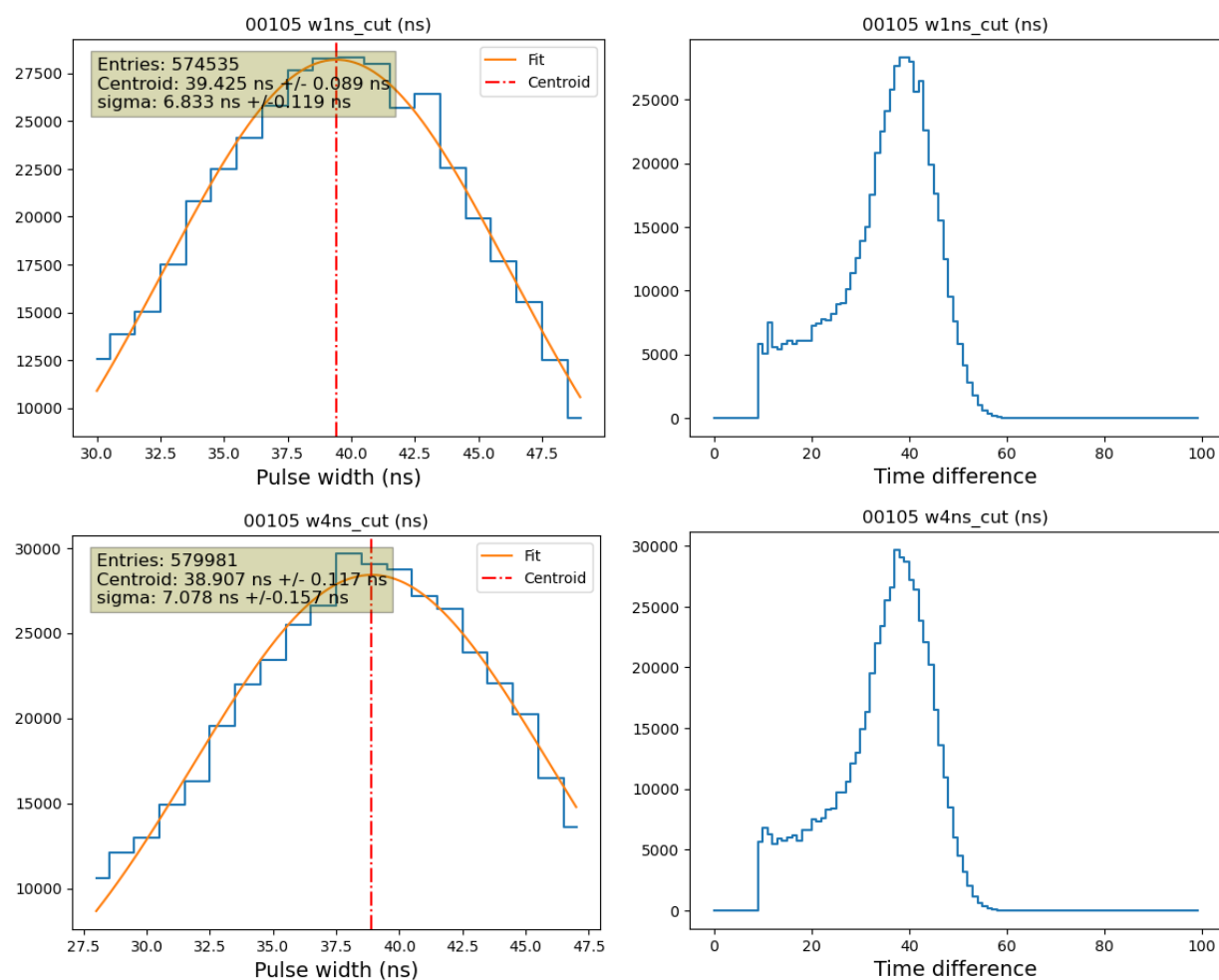
Figure 10: Pulse width histograms for w1 and w4 with the source over scintillator 1-4 for run 105.
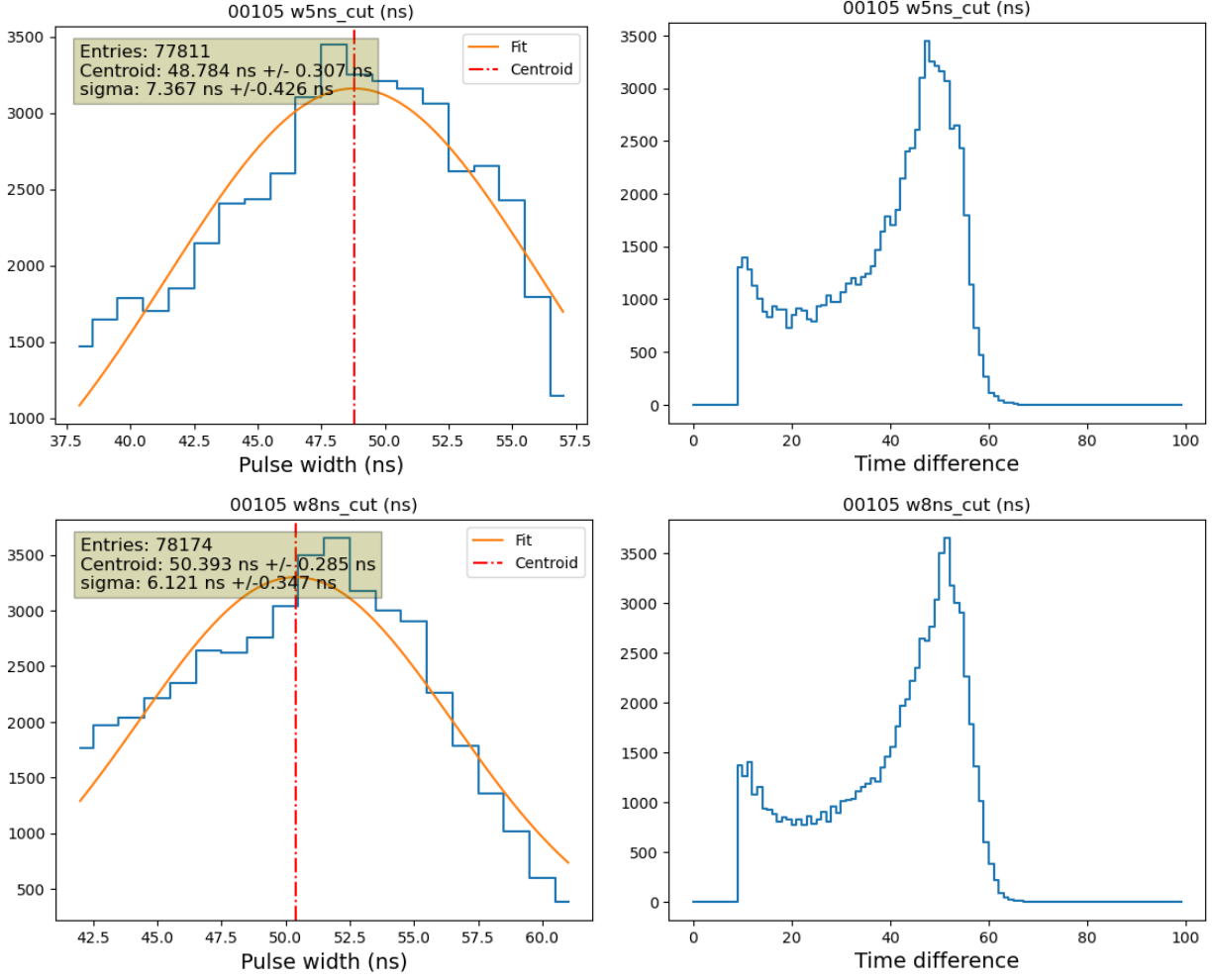
Figure 11: Pulse width histograms for w5 and w8 with the source over scintillator 1-4 for run 105.
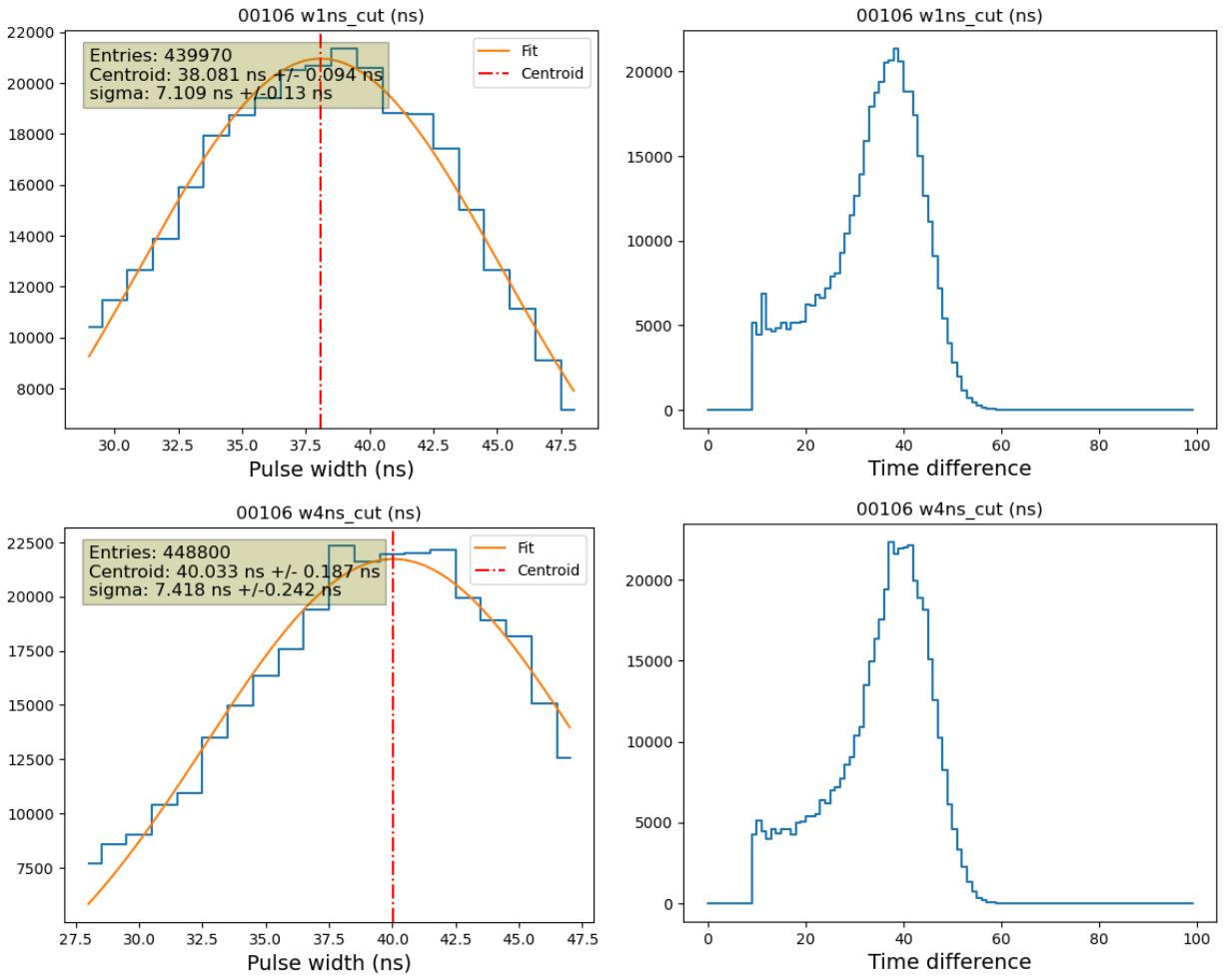
Figure 12: Pulse width histograms for w1 and w4 with the source over scintillator 1-4 for run 106.
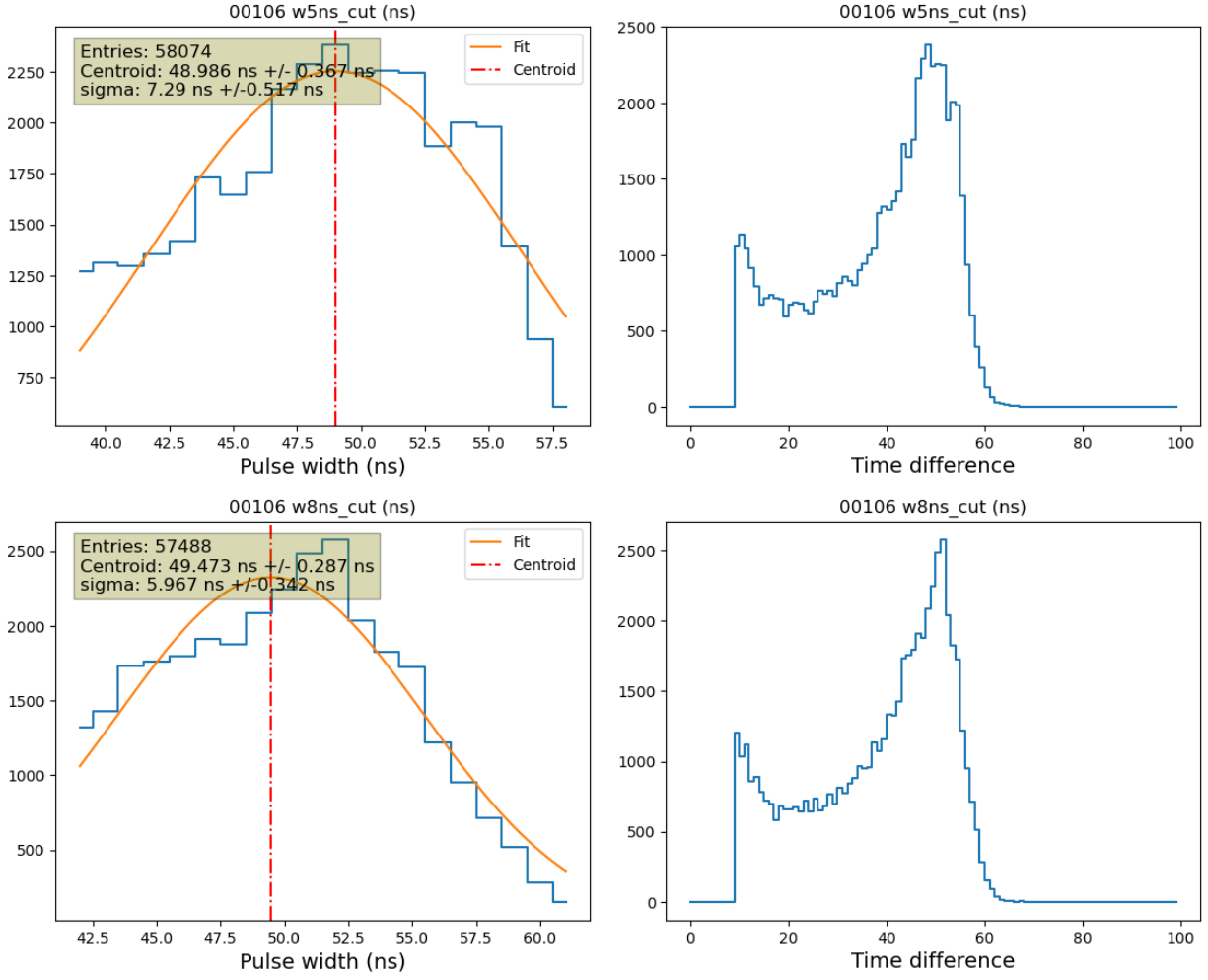
Figure 13: Pulse width histograms for w5 and w8 with the source over scintillator 1-4 for run 106.
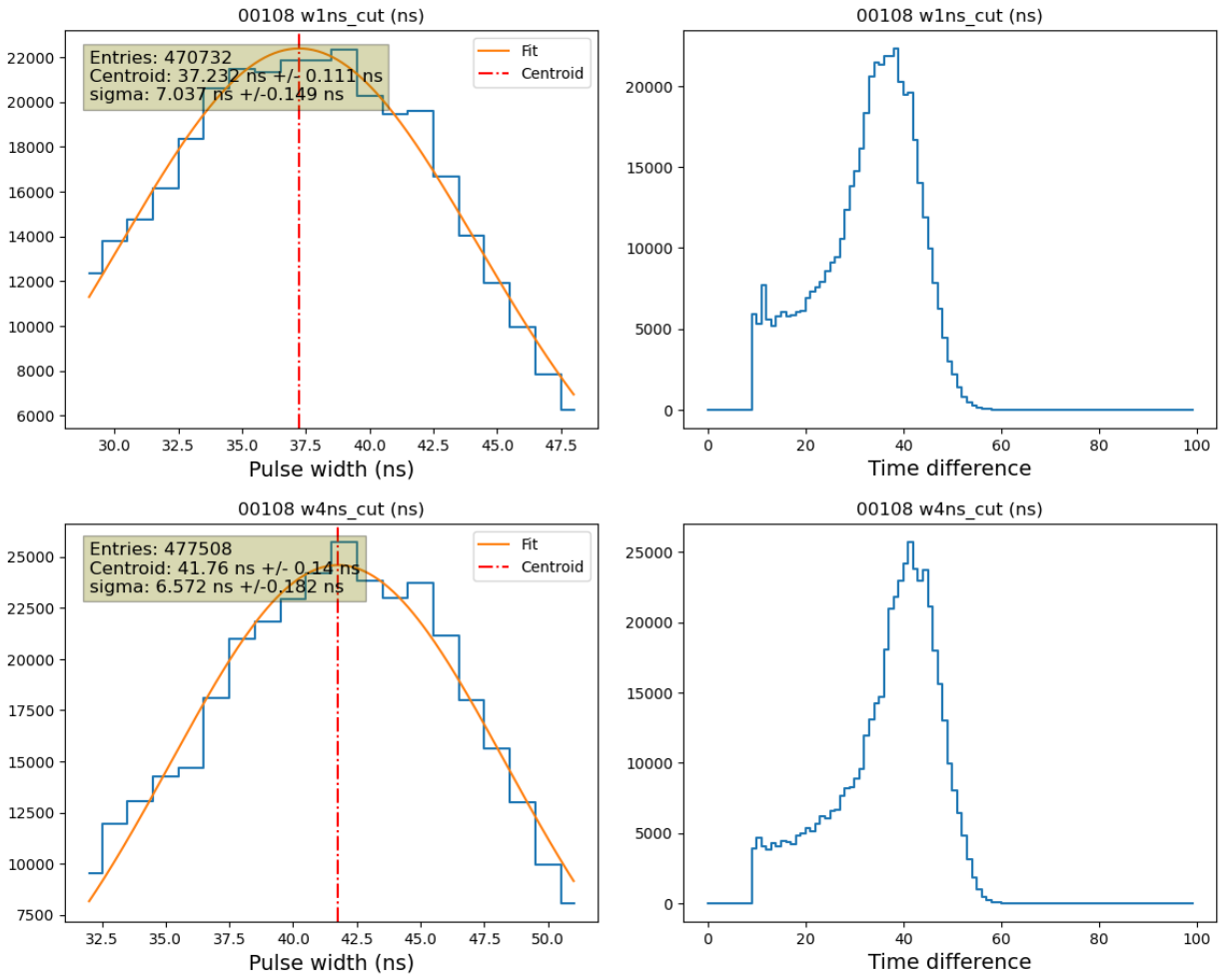
Figure 14: Pulse width histograms for w1 and w4 with the source over scintillator 1-4 for run 108.
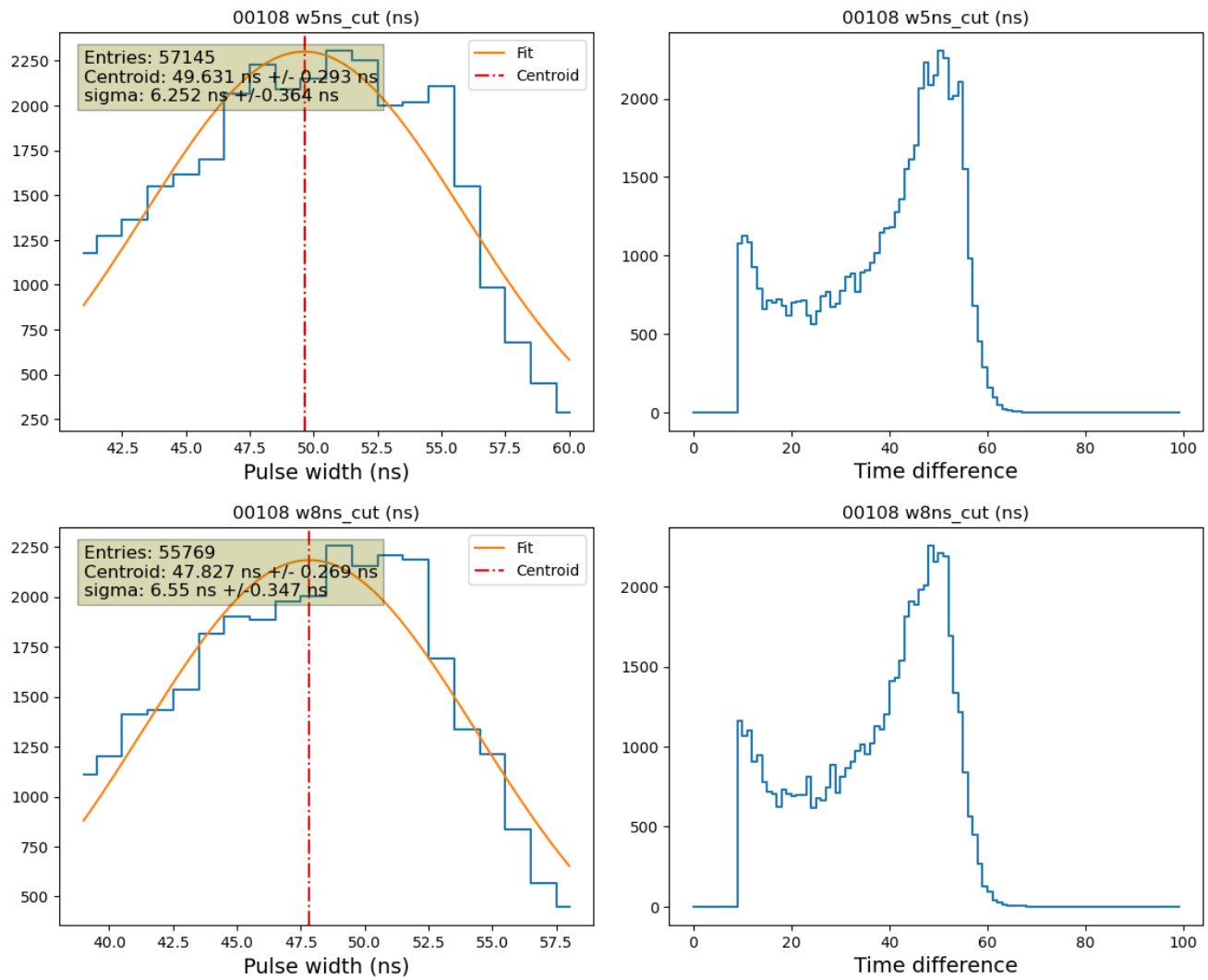
Figure 15: Pulse width histograms for w5 and w8 with the source over scintillator 1-4 for run 108.
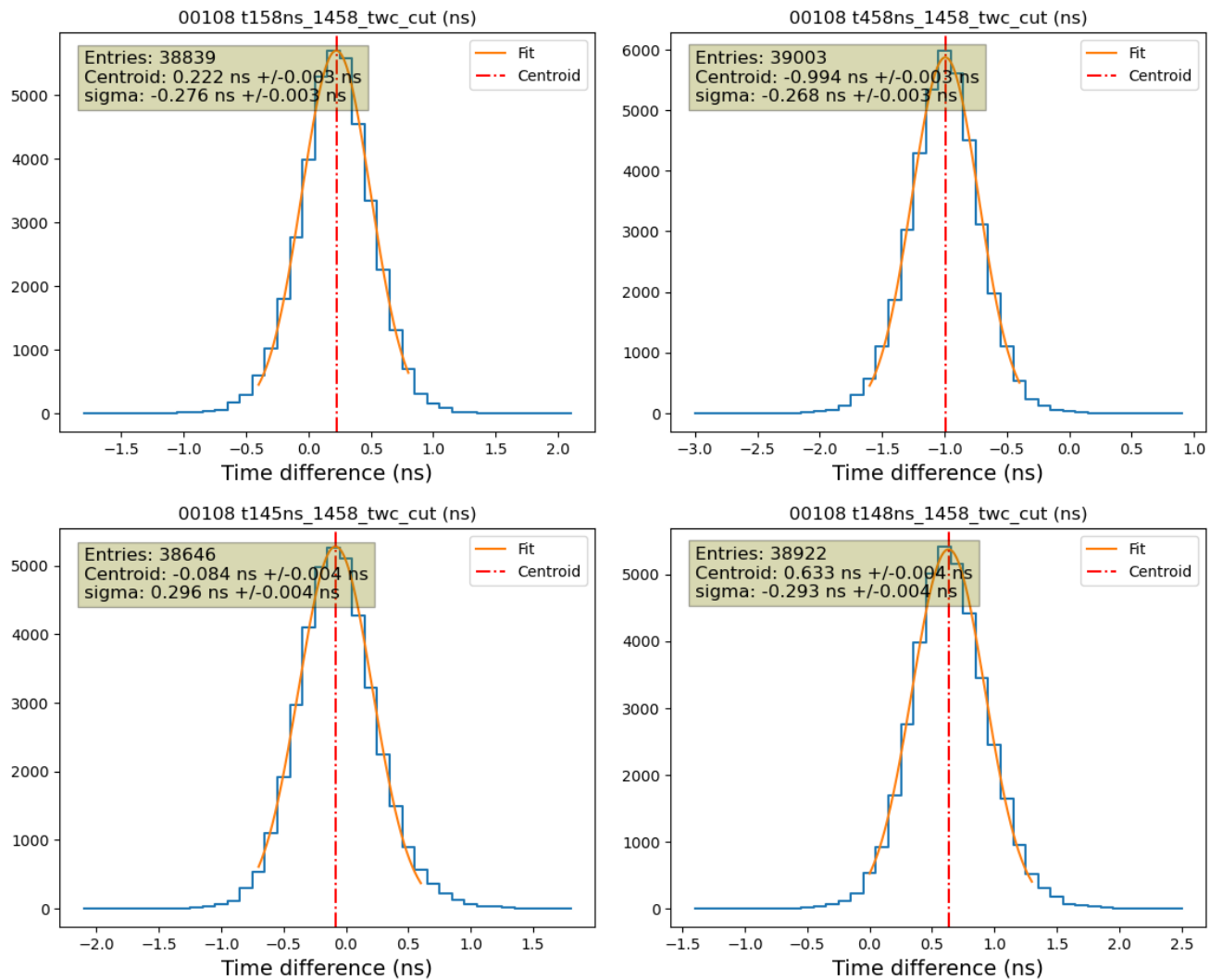
3 Absolute Time Histograms
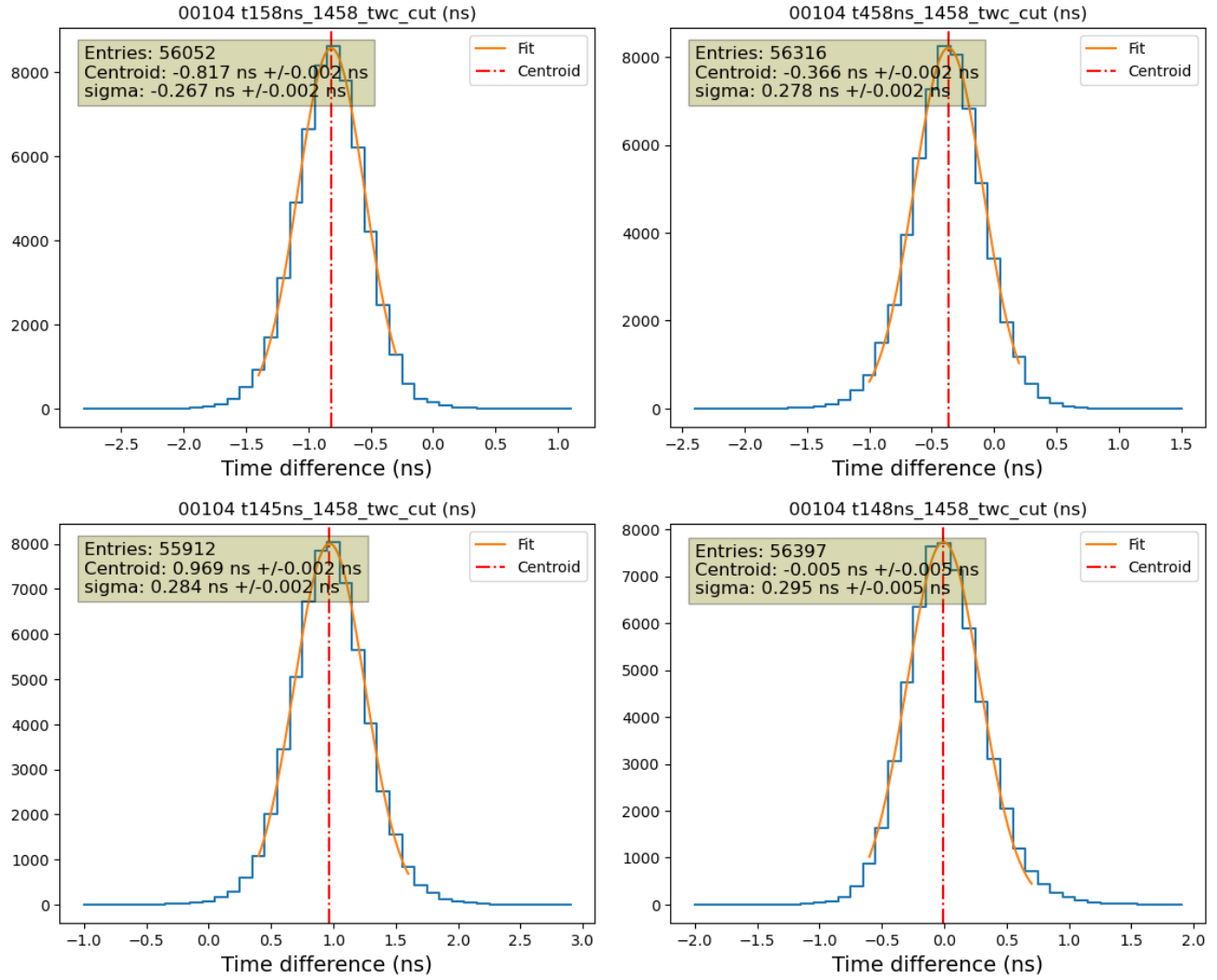
Figure 16: Time difference of the time of interest and the average time across the opposite bar for t1, t4, t5, and t8 with the source over 1-4 for run 104.
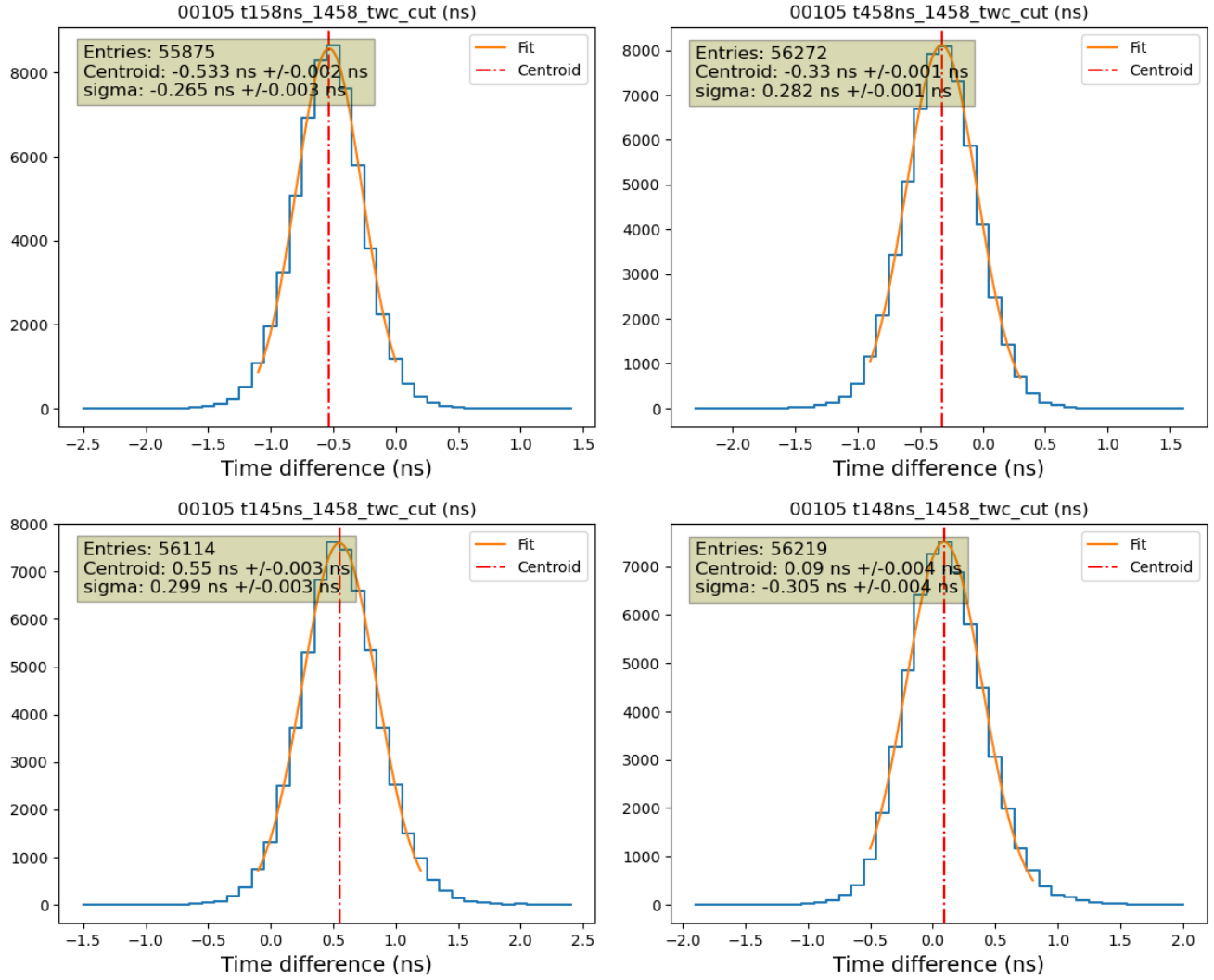
Figure 17: Time difference of the time of interest and the average time across the opposite bar for t1, t4, t5, and t8 with the source over 1-4 for run 105.
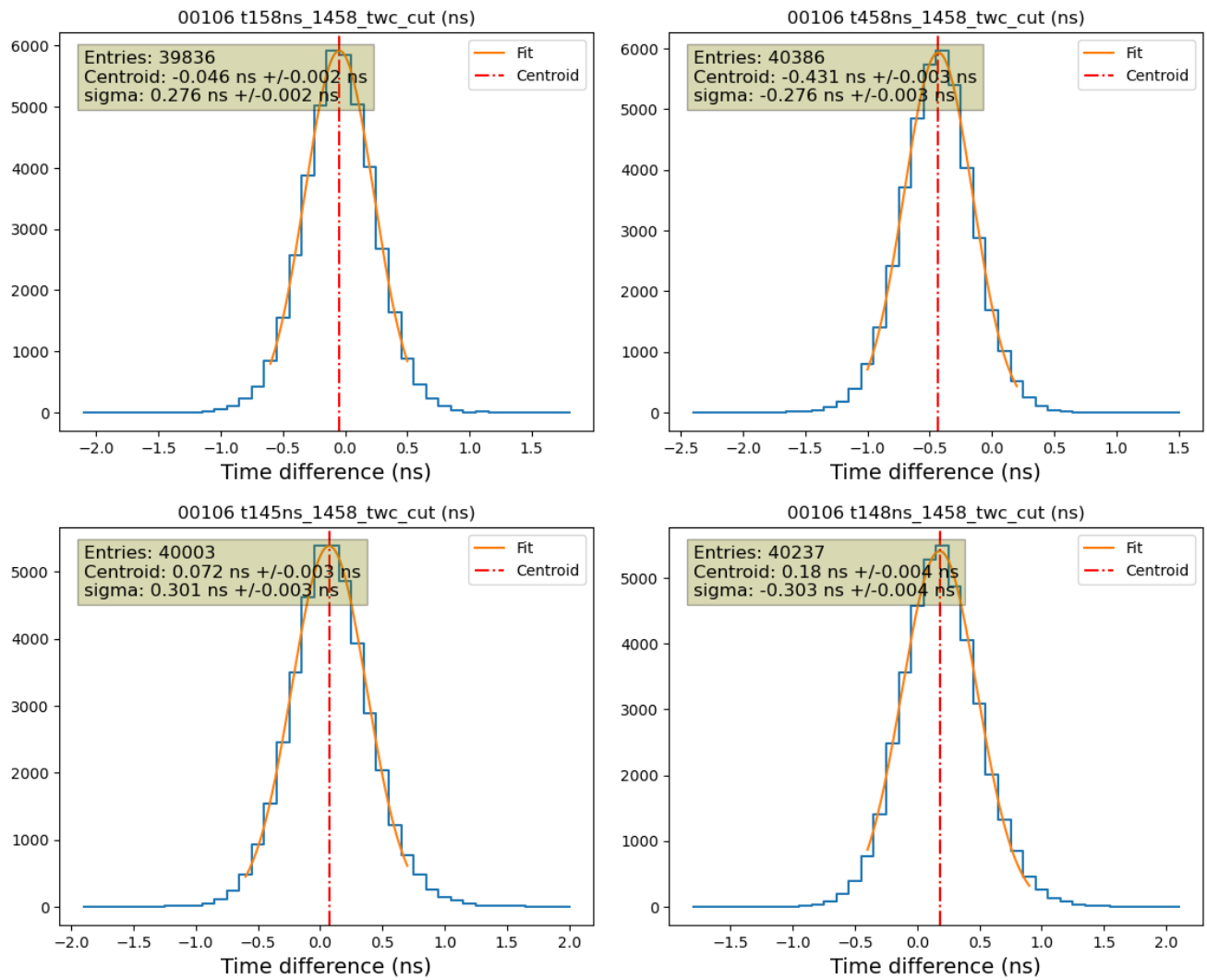
Figure 18: Time difference of the time of interest and the average time across the opposite bar for t1, t4, t5, and t8 with the source over 1-4 for run 106.

Figure 19: Time difference of the time of interest and the average time across the opposite bar for t1, t4, t5, and t8 with the source over 1-4 for run 108.
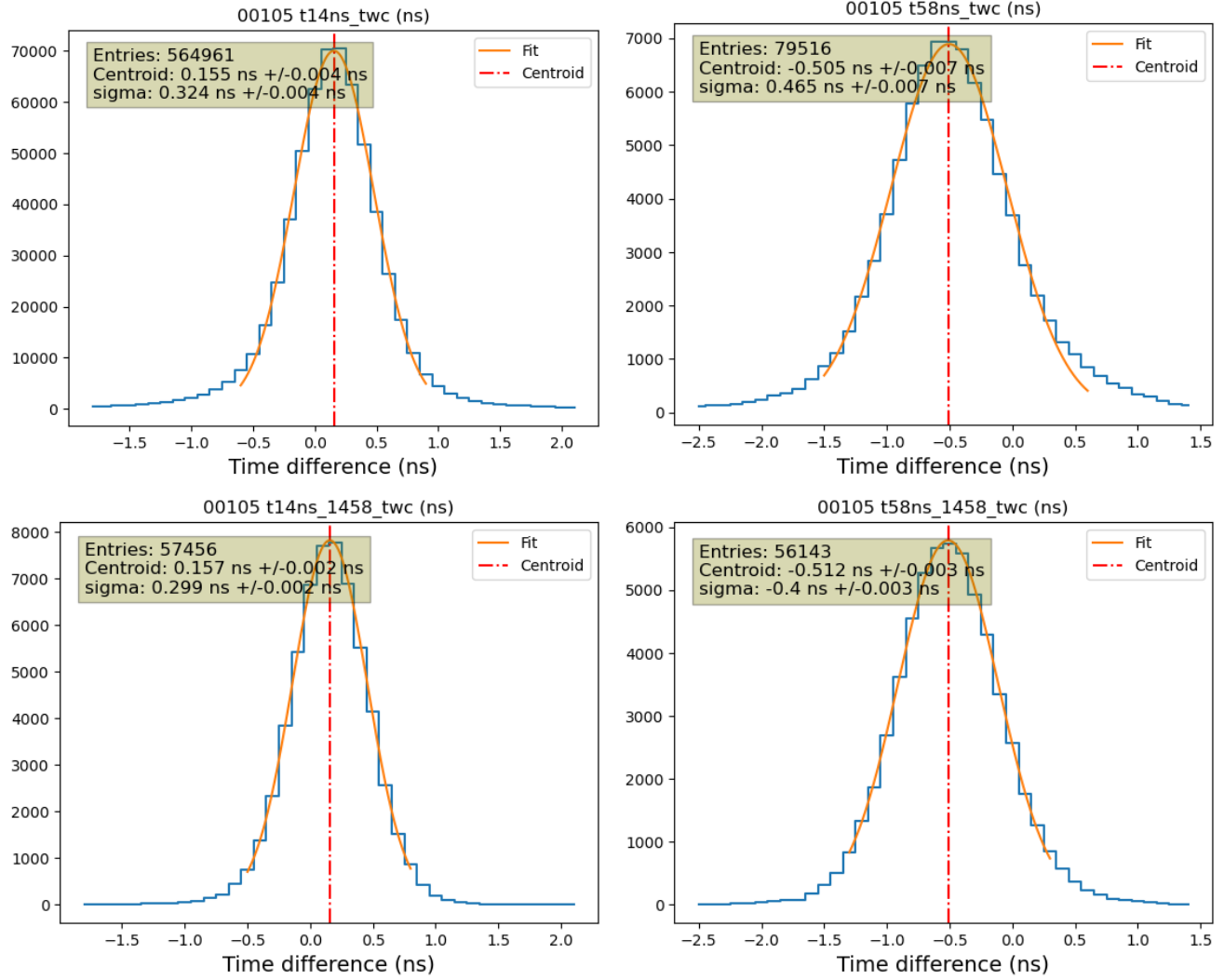
4 Time Difference Histograms
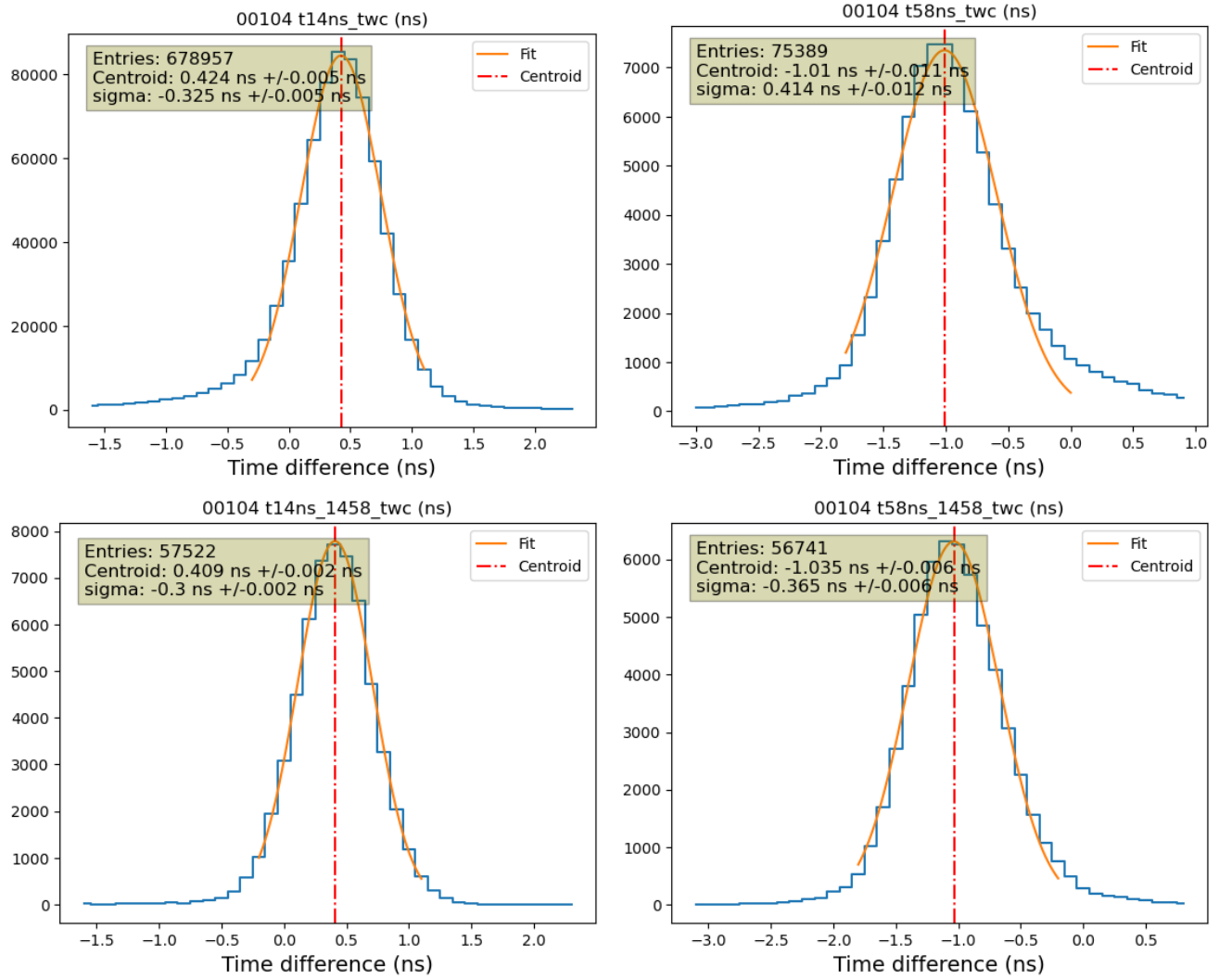
Figure 20: Time difference along a scintillator for $t_4 - t_1$ and $t_8 - t_5$ (time walk corrected) with a coincidence condition between the two paddles imposed on the lower plots for run 104.
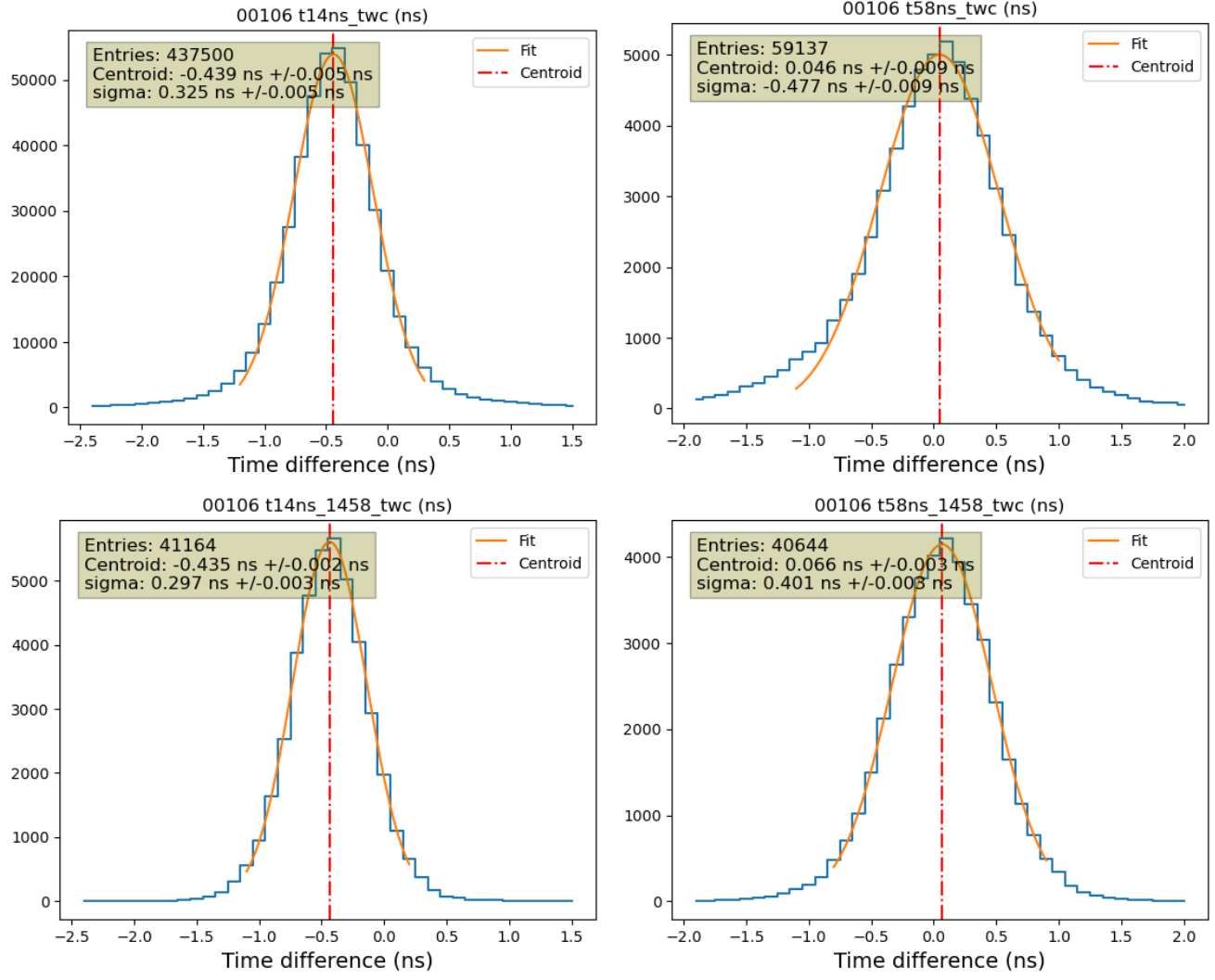
Figure 21: Time difference along a scintillator for $t_4 - t_1$ and $t_8 - t_5$ (time walk corrected) with a coincidence condition between the two paddles imposed on the lower plots for run 105.

Figure 22: Time difference along a scintillator for $t_4 - t_1$ and $t_8 - t_5$ (time walk corrected) with a coincidence condition between the two paddles imposed on the lower plots for run 106.
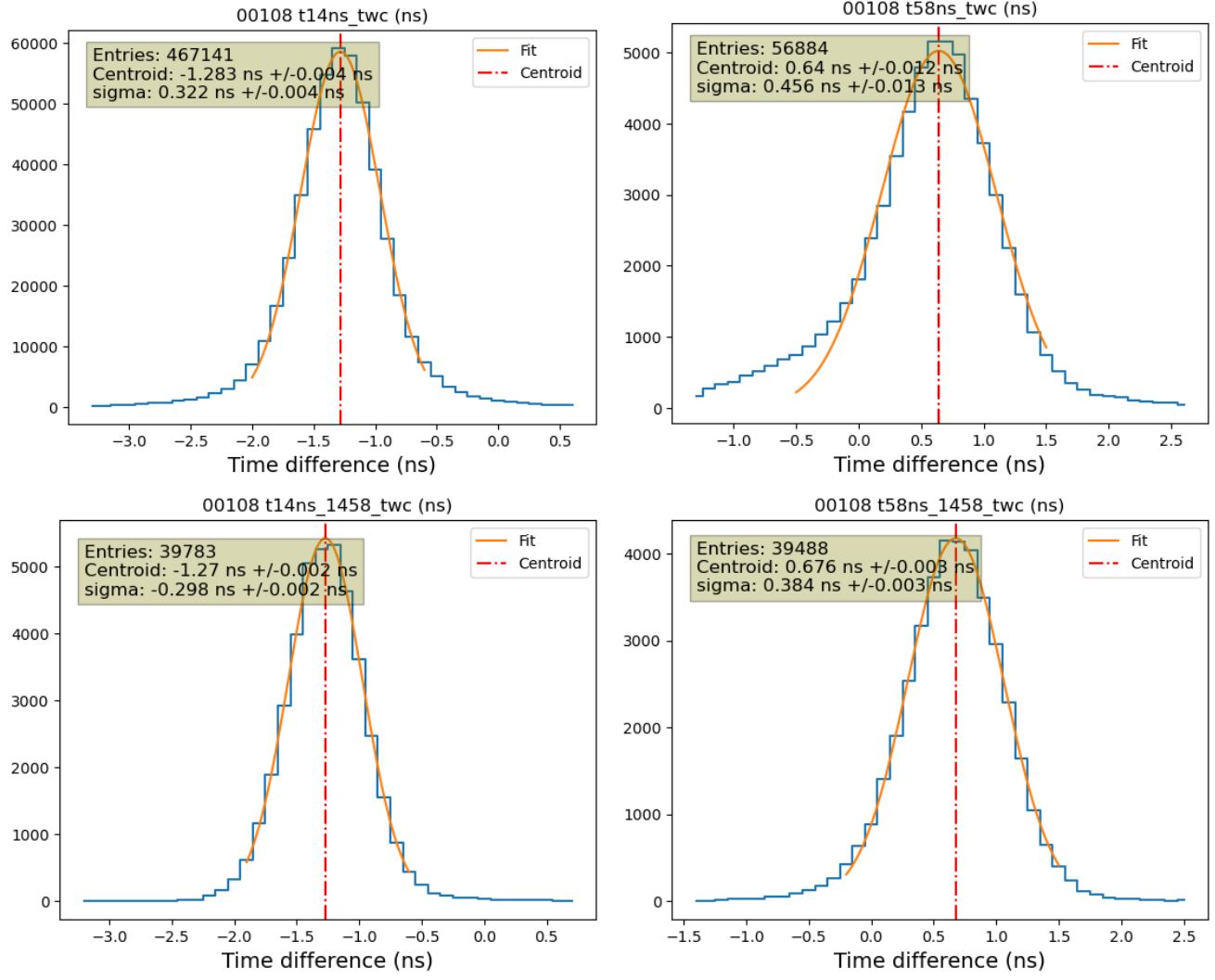
Figure 23: Time difference along a scintillator for $t_4 - t_1$ and $t_8 - t_5$ (time walk corrected) with a coincidence condition between the two paddles imposed on the lower plots for run 108.
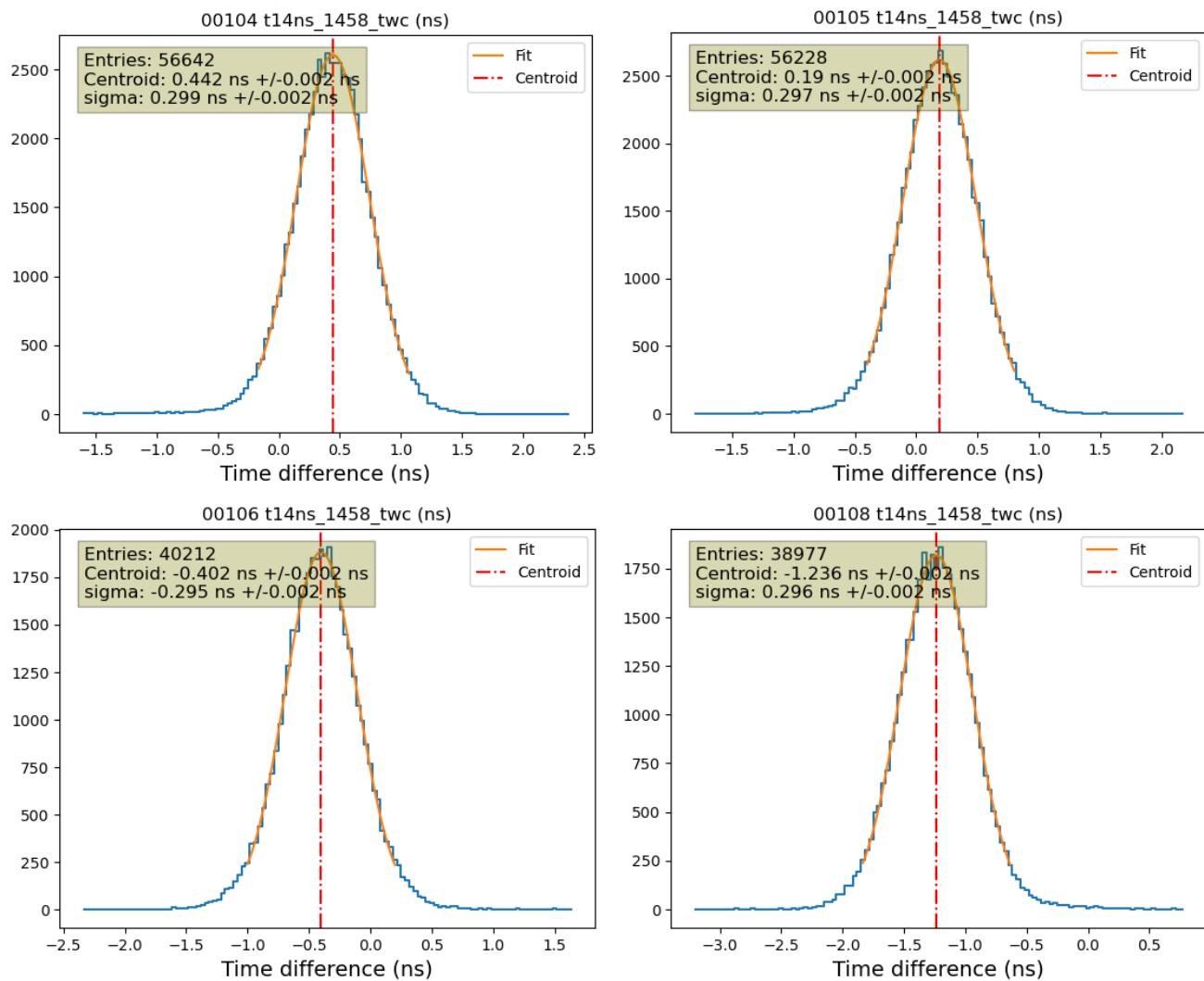
Figure 24: Time difference along a scintillator for $t_4 - t_1$ (time walk corrected) with a coincidence condition between the two paddles and using **600 bins**.
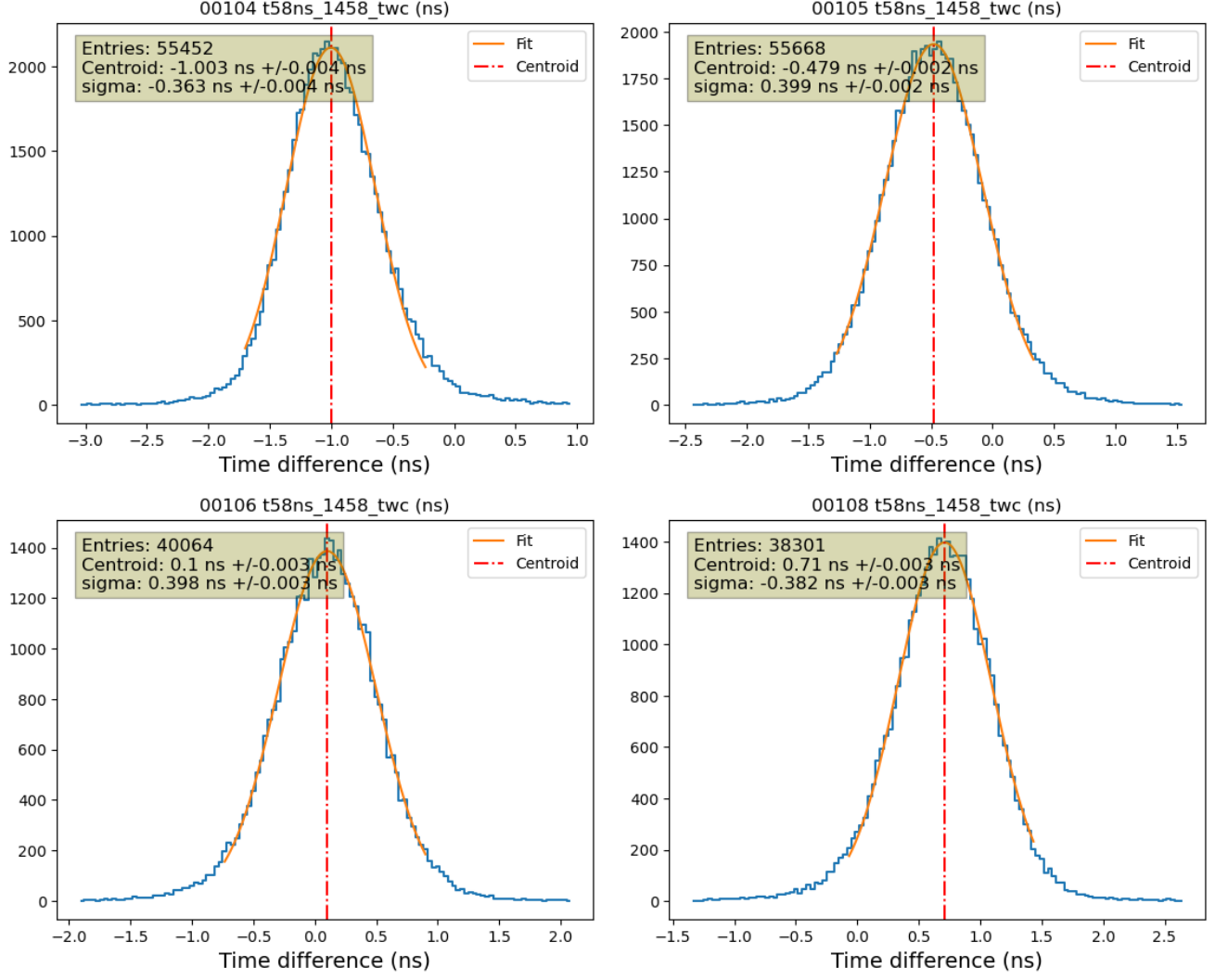
Figure 25: Time difference along a scintillator for $t_8 - t_5$ (time walk corrected) with a coincidence condition between the two paddles and using **600 bins**.