Timing Studies of Kuraray Scintillating Fibers

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1 Description

We report the results of the timing studies of the Kuraray 3HF fibers done at ODU. The goal of this study was to determine if the timing resolution of the fibers alone in the planned Start detector for Hall D would be sufficient for the experiment or if an additional conventional timing detector would be needed. In order to determine the resolution we have used the following setup.

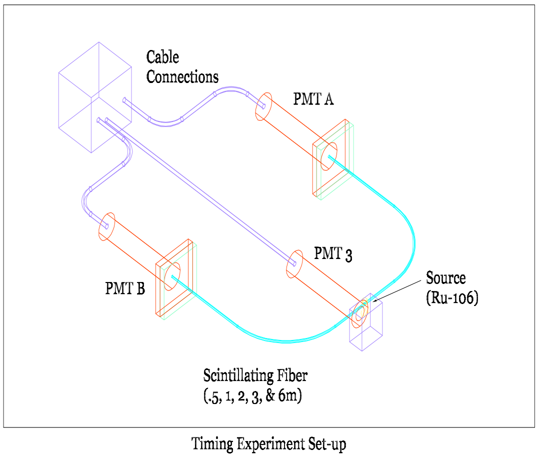

Figure 1: Setup for timing measurements

We used a ^{106}Ru source which was collimated to 1 mm. The trigger scintillator was a 1cm thick BC408 scintillator coupled to a Philips XP2282 tube. To measure the timing for different length fibers, we prepared a series fibers which were glued into plastic blocks and then polished. These were our couplings, which mated to a corresponding block glued to a XP2282 tube, with the whole aligned in the center of the PMT cathode. The signal produced from the PMT's was amplified and then split, with one signal going to the ADC's and the other to a constant fraction discriminator. The signal from the trigger scintillator was also sent to a CFD. An event was formed by the AND of all three signals, which then provided the start signal for the TDCs. The coincidence as set such that the start time was given by the trigger scintillator. All the electronics information was read out by CAMAC. Both TDC's were calibrated and the calibration for one is shown in the following two figure:

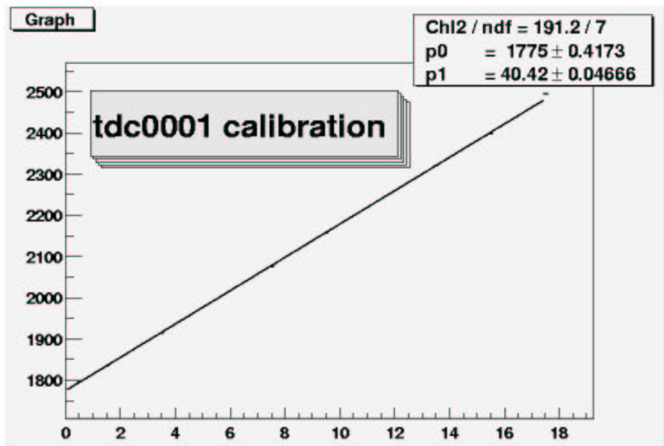

Figure 2: Time calibration for tdc0001

For each fiber we varied the location of the source and took several data points symmetric around the middle as well as a measurement in the middle to get the relative time zero.

As an example we measured the following positions for a 2 m long fiber, with respect to PMT A: 20cm, 40cm, 100cm, 160cm and 180cm.

2 Results

In order to test different geometries we have measured the timing distribution for 1m, 2m and 3m fibers. The data were analyzed in two different ways. The first one consisted in determining the offset of the two TDC's in respect to each other by carrying out a measurement in the middle of the fiber. The timing difference there should be zero in the ideal case. After this offset has been determined, the time difference was calculated on an event by even basis and the mean determined from a Lorentz fit. Since the standard deviation is not defined for a lorentzian fit, the FWHM are calculated. We then calculated a pseudo sigma by dividing the FWHM by 2.354. In Fig. **??** we plot TDC1 versus TDC2 for one of the measurements:

A typical time difference spectrum from a measurement is shown in the next figure:

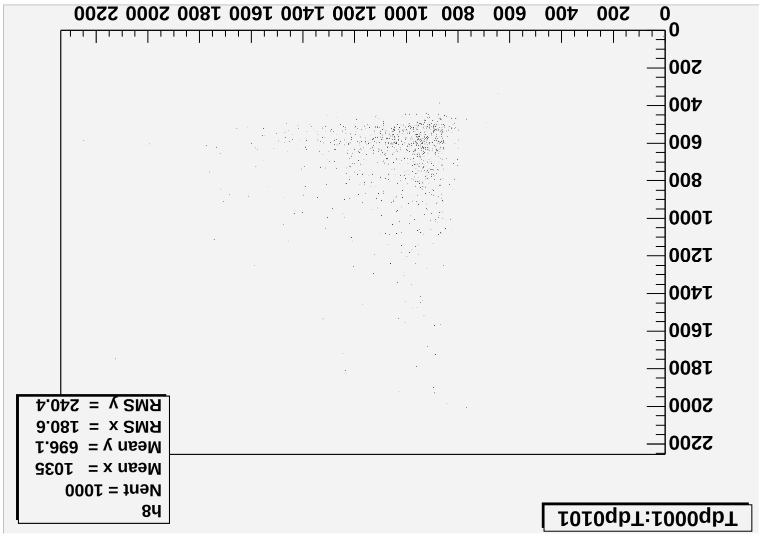

Figure 3: TDC 1 versus TDC2 for a two meter fiber with the source in the middle.

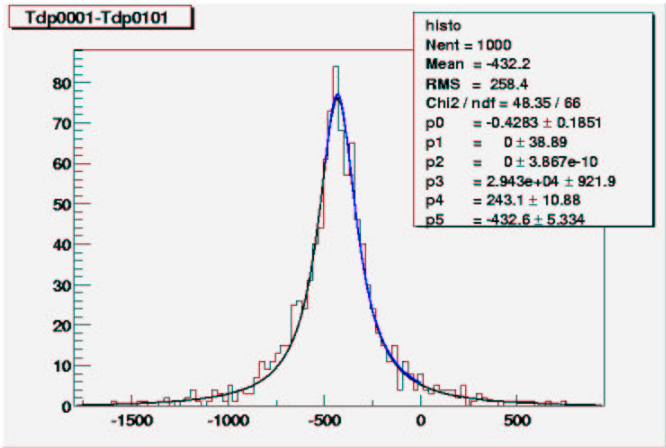

Figure 4: Time difference for a 2m fiber, source in the middle.

In Fig. 5 we plot the same time difference, but use the sum of two Gaussians to fit the data.

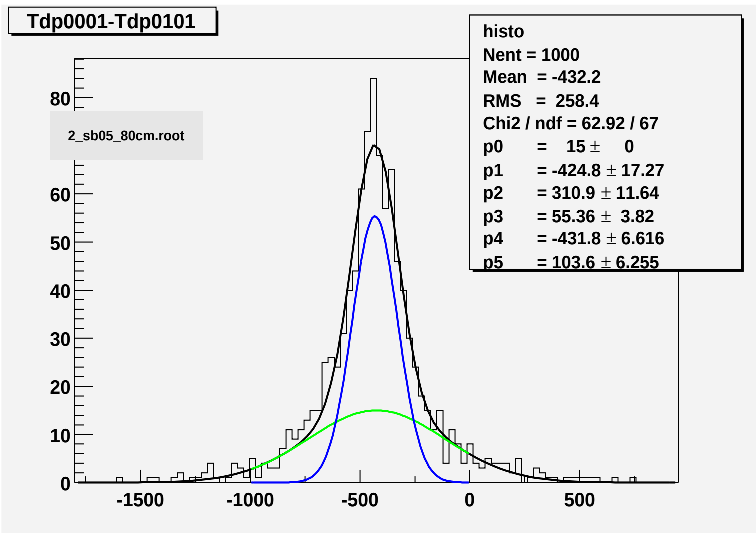

Figure 5: Time difference for a 2m fiber, source in the middle.

The results of all the measurements combined:

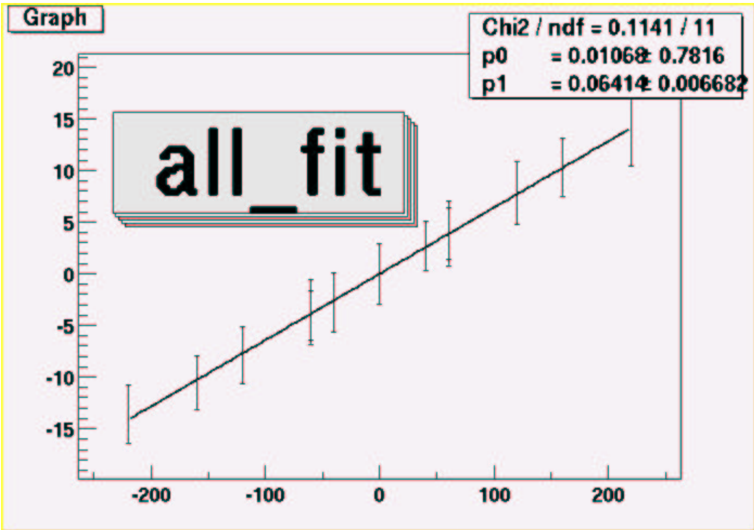

Figure 6: Overall fit of all timing difference measurements.

The result from this method gives an overall velocity of light in the fiber of 15.6 cm/ns ± 1.6 from the fit.

The second method consisted of analyzing the data from each PMT independently and then determining the difference from the average time of each PMT. Since the measurements have been made symmetrically around zero for different runs, this allows for determining the time difference without relying on the measurement at zero. The following plot shows the timing signal from one TDC and the landau fit used to determine the mean and sigma:

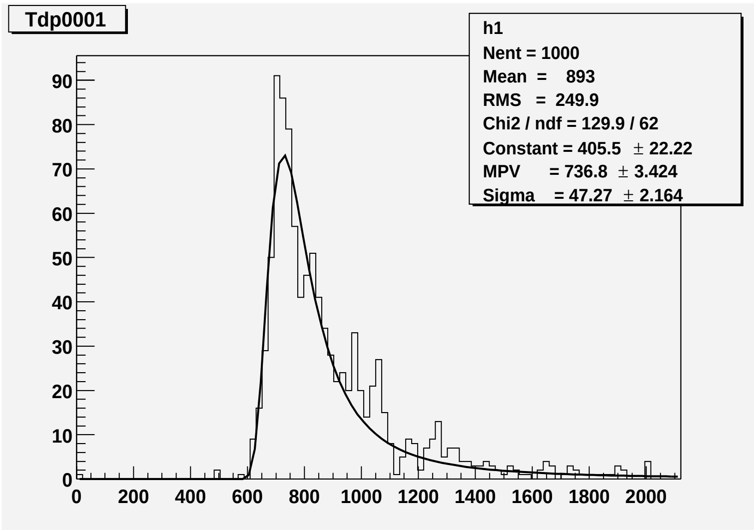

Figure 7: Timing signal from one PMT.

These measurements give an average velocity of 15.27 cm/ns ± .81 cm/ns.

3 Discussion

In order to get an estimate for the achievable timing resolution from the fibers we used the time difference distribution. To extract this we had to make the following assumptions:

- Each photomultiplier has the same time response; i.e.

$$\sigma_{\text{one tube}} = \sigma_{\text{time difference}}/\sqrt{2} \tag{1}$$

- The time resolution for a scintillating system is given by τ, TTS and NPE, where $\tau = 8ns$ is the decay time of the scintillator, TTS is the time transit spread of the PMT and NPE is the number of photoelectrons detected.

$$\sigma_{\text{Total}} = \sqrt{\frac{\tau^2 + TTS^2}{NPE}} \tag{2}$$

- The quantum efficiency (Q) of the Hamamatsu tube at 530 nm is 12 %, while the QE for the VLPC Histe IV is 60 % at this wavelength.

(Actually the newest VLPC have a QE closer to 80 %). So in order to estimate the VLPC NPE, we multiplied the estimated PMT NPE by a factor of 5.

In the following table we present the results from our measurements for different fiber length and positions of the source.

Results									
speed of light cm/ns		29.98						2.354	
Fiber		Position	FWHM	"sigma"	sig in ns	Sig one tube	NPE	VLPC NPE	VLPC sig
sd05		40	352.4	149.70	3.74	2.65	9.28	46.41	1.18
	300	150	273.1	116.02	2.90	2.05	15.45	77.27	0.92
		260	268.8	114.19	2.85	2.02	15.95	79.76	0.90
				0.00	0.00	0.00			
sb05		20	262.5	111.51	2.79	1.97	16.73	83.63	0.88
	100	30	230	97.71	2.44	1.73	21.79	108.94	0.77
		50	268	113.85	2.85	2.01	16.05	80.24	0.90
		70	273	115.97	2.90	2.05	15.47	77.33	0.92
		80	243	103.23	2.58	1.82	19.52	97.60	0.82
				0.00	0.00	0.00			
sb04		20	268.4	114.02	2.85	2.02	16.00	80.00	0.90
	100	50	274.6	116.65	2.92	2.06	15.29	76.43	0.92
		80	271.2	115.21	2.88	2.04	15.67	78.36	0.91
				0.00	0.00	0.00			
sc02		20	265	112.57	2.81	1.99	16.41	82.06	0.89
	200	40	280	118.95	2.97	2.10	14.70	73.51	0.94
		100	305	129.57	3.24	2.29	12.39	61.95	1.02
		160	265	112.57	2.81	1.99	16.41	82.06	0.89
		180	241	102.38	2.56	1.81	19.84	99.22	0.81
Average			271.31	115.26	2.88	2.04	16.06	80.30	0.91
STD			27.5834	11.72	0.29	0.21	2.86	14.29	0.09

Figure 8: results

This table lists the measurement we have done for the timing properties. The total fiber length is given in column 2, the position refers to the distance of the source in respect to tube A, and FWHM is the width of the Lorentz fit. Sigma refers to FWHM/2.354 and "sig in ns" is the same but multiplied by the TDC resolution of 25 ps/channel. NPE is the estimated number of photo electrons from Eq. 2 and the VLPC NPE expresses the scaled number which would be seen by the VLPC's. The last column then expresses the expected timing resolution using one fiber and the VLPC's. At the bottom of the table are the averages and standard deviations for all the measurements.

From this measurement it seems clear that a resolution of .91 $\pm$ .09 ns is achievable with one fiber. If one uses the fact that we have at least three fibers hit in the planned geometry, the projected timing resolution is expected to be better than 600 ps. However, in order to test this prediction, it is clear that a small prototype with VLPC's has to be constructed.