REPORT ON TIMING AND SIGNAL STUDIES FOR THE HALL D START DETECTOR

W. U. Boeglin
Physics Department
Florida International University
Miami FL 33199
Physics Division Jefferson Lab
Newport News, Virginia, 23606

May 30, 2003

The measurements described in this report have been carried out under the assumption that the scintillating fibers will not be able to provide the necessary time resolution for timing measurements. Therefore we planned a separate detector for timing measurements, the start detector, consisting of an array of scintillators which closely surround the target.

We purchased two scintillation materials from Eljen Technologies which seemed suitable for this application. The materials are:

- EJ-204 is a fast scintillator with a rise time of 0.7 ns and a decay time of 1.8ns. It also has a large light output.
- EJ-208 is a scintillator that is slower with a rise time of 1ns and a decay time of 3.3ns.

The advantage of EJ-208 over EJ-204 is its larger attenuation length which allows one to build very large detectors. For real fast timing EJ-228 would be ideal but the short attenuation length permits detector sizes of up to 10cm only. A third possibility now exists using EJ-230 with which one should be able to build detectors up to 100cm according to the manufacturer.The rise time of EJ-230 is 0.5 ns and its decay time 1.4ns.

We have purchased two identical bars of 0.5cm x 3cm x 70cm of EJ-204 and EJ-208. These dimensions are very close to the actual size of the individual detectors if we do not install a conical section to cover the forward region.

We purchased two Hamamatsu H2431-50 systems which are fast, high-gain photomultipliers. We have attached the scintillator bars to these PMT's and measured the timing properties as well as the amplitudes as a function of position along the scintillator. In this way we expect to obtain the best possible time resolution.

Since we expect a sizeable magnetic field at the location of the photo multipliers in the start detector we also purchased two different types of PMT from Hamamatsu that can be operated in a high magnetic field environment. The system H6152-01 uses the tube R5505 which is one of the fastest tubes for high magnetic field applications but has a relatively low gain of $5.0 \cdot 10^5$. The other system is the H6614-01 with a R5942 tube that has a high gain of $1 \cdot 10^7$ but is slower than the first tube. So far we have carried out measurements using the H6614-01 system which allows us to easily change phototubes for comparative measurements.

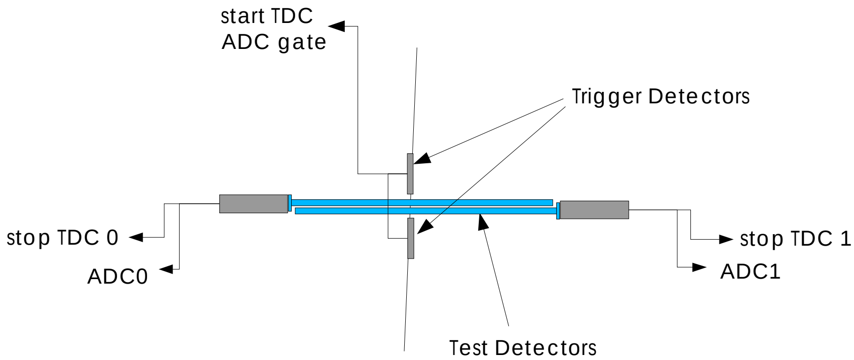

Figure 1: Test setup for timing studies on scintillator bars for the start detector.

Measurements on the scintillator bars have been carried out using cosmic rays. The current cosmic ray trigger setup is show in figure 1 and contains 2 small scintillators which are oriented perpendicular to the scintillators being tested. With this arrangement we trigger on cosmic rays that cover an area that is only about 1cm wide. In this way the width of the distribution of cosmic rays contributes only about 20ps to the time resolution. The coincidence of the two detectors provide the start signals for the TDC's. The stop signals are provided by the start detector scintillator bars. As shown in figure 1 the test detectors are oriented such that the two photo multipliers are at opposing each other. A typical spectrum of the time difference between the right and the left detectors is shown in figure 2 The cosmic ray trigger is also used to generate a common adc gate for all detectors. For the data acquisition system we use the CODA. We developed the necessary software based on root that allows us to analyze coda files created by this setup. A sample adc spectrum with the H2431-50 system is shown in figure 3. The different colors indicate the different positions of the trigger with respect to the left photo tube. The red curve corresponds to the largest distance of 47 cm from the PMT. The cyan curve corresponds to the closest distance of 15.5 cm and the blue corresponds to 34.5 cm which corresponds to the middle

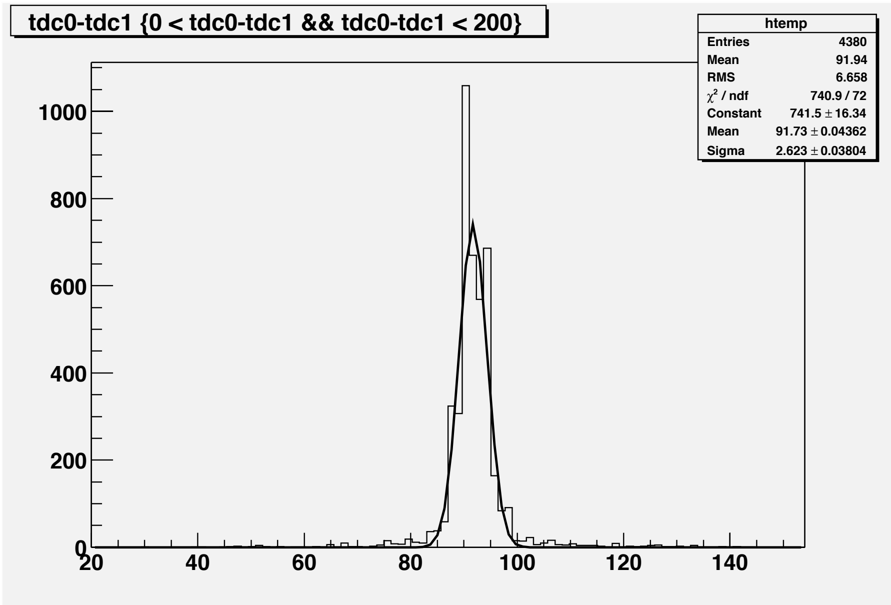

Figure 2: Time difference spectrum between two scintillator bars (1 ch = 0.1 ns)

position between the two PMT's. The position of the peak corresponding to minimally ionizing cosmic ray particles has been fit as a function of position along the scintillator bar. The size of the PMT signal varies due to absorption in the scintillator material and light loss due to multiple internal reflections. We have wrapped the scintillator with "VAC_PAK" a material similar to "Tedlar" which minimized the contact with the scintillator surface in order to minimize degradation of internal reflection. We have not added any reflective materials when wrapping the scintillators. The measured peak position as a function of trigger scintillator position is show in figure 4 for the left PMT and in figure 5 for the right one. An exponential $P(x) = A_0 e^{-\alpha x}$ has been fitted to both set of data. For the left detector (ADC0) we obtained $A_{left} = 599$ and $\alpha_{left} = -8.6exx{-}3 \pm 2{\cdot}10^{-4}$ and for the right detector (ADC1) we obtained $A_{right} = 232$ and $\alpha_{left} = 10.4{\cdot}10^{-3} \pm 2{\cdot}10^{-4}$. If one translates this to an effective absorption length we obtain $\lambda_{left} = 116$ cm and $\lambda_{right} = 94.3$ cm From this we can conclude that both materials would be suitable for the start detector.

In order to study the timing properties of the scintillators we measured the time difference between the left (TDC0) and the right (TDC1) detector

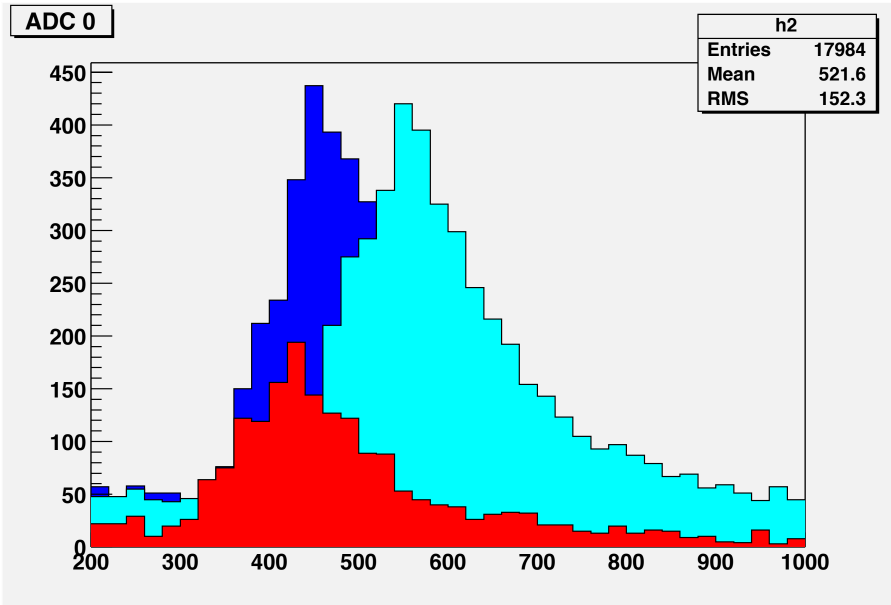

Figure 3: ADC spectra for cosmic rays for the H2431-50 (left) system. Red: 47 cm from the PMT. Cyan: 15.5 cm from PMT. Blue: 34.5 cm from PMT

as a function of position. From these data we also determined the averaged speed of light in the two scintillators. The results are shown in figure 6. The slope of the line that has been fitted corresponds to $p1 = \frac{(c_1+c_2)}{c_1 c2}$ where c_1 and c_2 are the speed of light in the 2 scintillator materials. From the width of the peak in the time difference we obtain information on the resolution. For simplicity we assumed that both scintillators have the same resolution and the individual variation is $\sigma_{tot}/\sqrt{(2)}$. The resulting resolution (σ) is show in figure 7 as a function of position. The best combined time resolution of $190ps$ is obtained in the middle of the detector. This is due to the fact that the time resolution degrades slightly if one approached the end of the scintillator bar. The two scintillators are oriented in opposite directions and therefore small values of x correspond to large distances from the right PMT and large values of x mean large distances from the left PMT.

The response of the H6614-01 high field PMT is shown in figure 8 From this measurement we determine the time resolution of the left scintillator in combination with the high field PMT to be about 250 ps which results in a FWHM resolution of 600 ps. This will allow us to resolve the RF structure

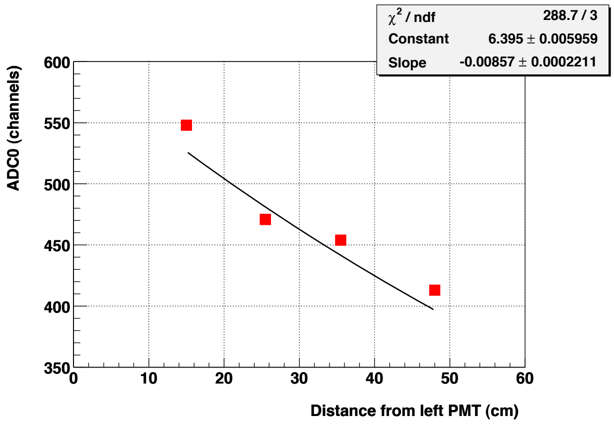

Figure 4: ADC peak position for cosmic rays as a function of trigger detector position for the left PMT

of the electron beam and identify individual electron packets.

The observed properties of scintillating fibers suggest that it is possible to obtain timing information from the scintillating fibers. While a single fiber cannot deliver the necessary time resolution a combination of timing measurements from all 6 super-layers should be able to. If this can be confirmed we could save about 5mm of scintillation materials close the the target. This would be very beneficial to the resolution of the detector since the scintillator array adds a considerable amount of multiple scattering to the particle trajectories.

We have therefore decided to stop further studies of the scintillator bars and focus instead on timing studies of the scintillating fibers. To this end we ordered a 32 channel VME tdc and 32 channels of discriminators. In the future we will aquire a VLPC cassette from FERMILAB with about 100 channels which will allow us to build a small stack of scintillating fibers and start measurements of their combined timing properties

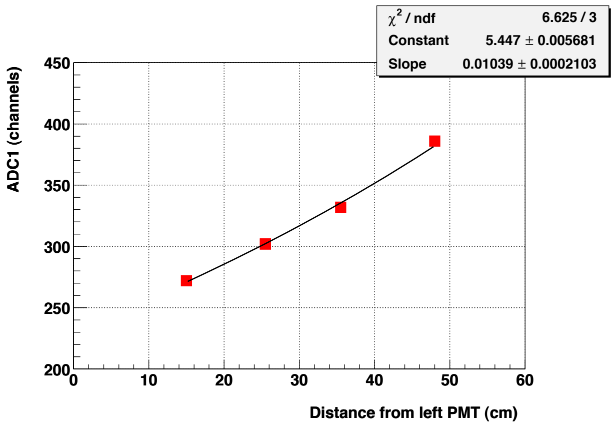

Figure 5: ADC peak position for cosmic rays as a function of trigger detector position for the left PMT

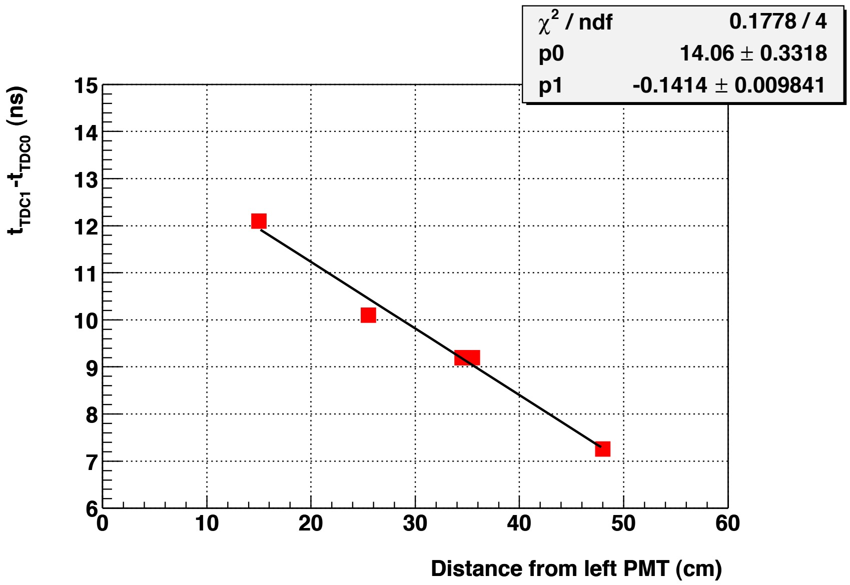

Figure 6: TDC difference peak position for cosmic rays as a function of trigger detector position for the left PMT

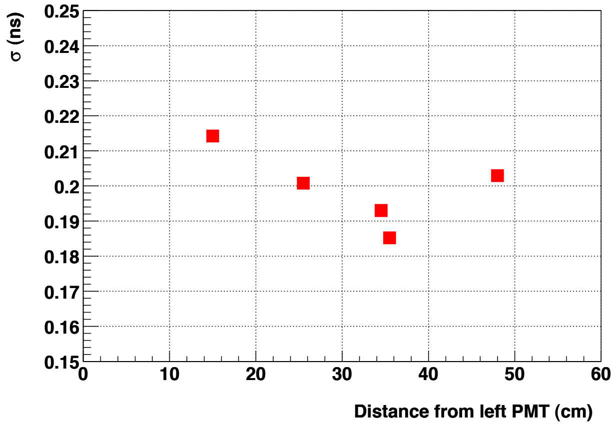

Figure 7: The time resolution (σ) as a function of detector position

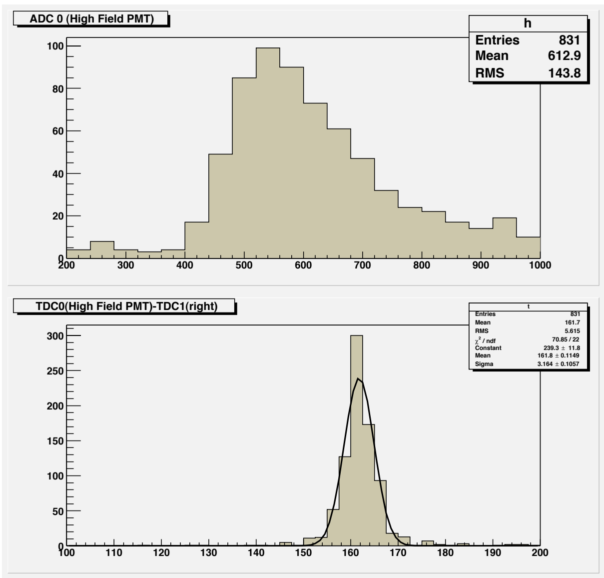

Figure 8: ADC spectrum (top) and TDC difference spectrum for the H6614-01 high field PMT