Data Definitions for the CLAS Drift Chambers

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1. Introduction

In this CLAS-Note we describe some of the responsibilities of the drift chamber software group and define the data structures necessary for analysis and monitoring of the CEBAF Large Acceptance Spectrometer (CLAS) drift chambers. The CLAS is a large, complex detector with many different sub-components including more than 34,000 sense wires in its drift chambers. A typical event will contain over 5,000 bytes of data collected at a rate of about 1000 events per second. The analysis software is appropriately complicated. In this CLAS-Note we describe how the signals produced by the passage of a scattered particle through the CLAS propagate through the system. We will use this sequence to show how one determines the drift time from the readings in the time-to-digital-converters (TDC's) of the drift chambers. This drift time is an essential component in the reconstruction of the trajectory of the scattered particle. We then outline the analysis of an event with the aim of defining the drift chamber group's responsibilities within that analysis.

2. Time Components of a CLAS Event

In a typical CLAS event a charged particle produced at the target passes through thirty-four layers of drift chamber sense wires, leaving behind a trail of ionized atoms in each drift chamber cell the track passes through. This charge slowly migrates towards the positive-voltage sense wire. The scattered particle also passes through a plastic scintillator producing a prompt signal that provides the earliest warning that an event has occurred. This signal is used to stop the scintillator counter TDC after a start signal arrives from the Level 1 (L1) trigger. At forward angles the scattered particle also passes through a Cerenkov counter and enters a large calorimeter. These devices are used to identify electrons and measure high-energy photons. At some time after the passage of the scattered particle the ions produced in the drift chambers will reach their respective sense wires and produce a start signal for the TDC's. A stop for the drift chamber TDC's is provided later by the Level 1 trigger. Notice that in this sequence the actual arrival time of the beam at the target is unknown and the drift time is only indirectly related to the time measured in the TDC's.

We now describe the components of the measured time signals of a CLAS event as shown in Figure 1. The sequence of steps in the scintillator is shown in the time lines starting at the top and moving down to the middle. The sequence of steps in a typical drift chamber cell is shown starting from the bottom and going up to the middle. In the center of the figure the signals associated with the Level 1 trigger in the data acquisition system are included [1]. Each step in the sequence is labeled on the right. Time differences between steps that will be the same from one event to the next are marked with solid arrow-heads. Time differences that are different for each event are marked with open arrow-heads.

For the scintillator the initial time difference is the flight time of the scattered particle from the target to the scintillator. Once the scattered particle passes through the scintillator the burst of photons propagates down the scintillator to reach the photo-multiplier tubes. The signal propagates through a long cable and eventually provides a stop signal for the scintillator TDC. The start for that TDC had been provided earlier by the Level 1 (L1) trigger. This trigger signal has a 20 ns time jitter in it so the scintillator TDC signal is not by itself an accurate measure of the timing.

In the drift chamber, after the scattered particle passes through the drift cell the ions drift into the sense wire. The current pulse produced on the sense wire propagates down the long sense wires to the pre-amplifier. After processing at the pre-amplifier the signal passes through long cables to a post-amplifier and then to the start of the drift chamber TDC's. The stop for the drift chamber TDCs comes from the Level 1 trigger at a fixed time difference after its start ($T_{\Delta L1}$). Hence, it suffers from the same 20 ns time jitter mentioned above.

We now describe how to extract the drift time from these components. The times measured by the scintillator and drift chamber TDC's are labeled as T_{SC} and T_{DC}, respectively. We define the time difference T_{trig} as the time between the arrival of the beam and the arrival of the Level 1 trigger start at the scintillator TDC. It is not measured, but it provides a useful tool to calculate the drift time. An expression for T_{trig} can be written in terms of the components of the scintillator time steps of Figure 1 by starting from the top of the figure and going down step by step.

$$T_{trig} = T_{flSC} + T_{propSC} + T_{delaySC} - T_{SC} - T_{LSC} \tag{1}$$

Equation 1 can be rearranged to give the following expression for T_{SC} which is the quantity

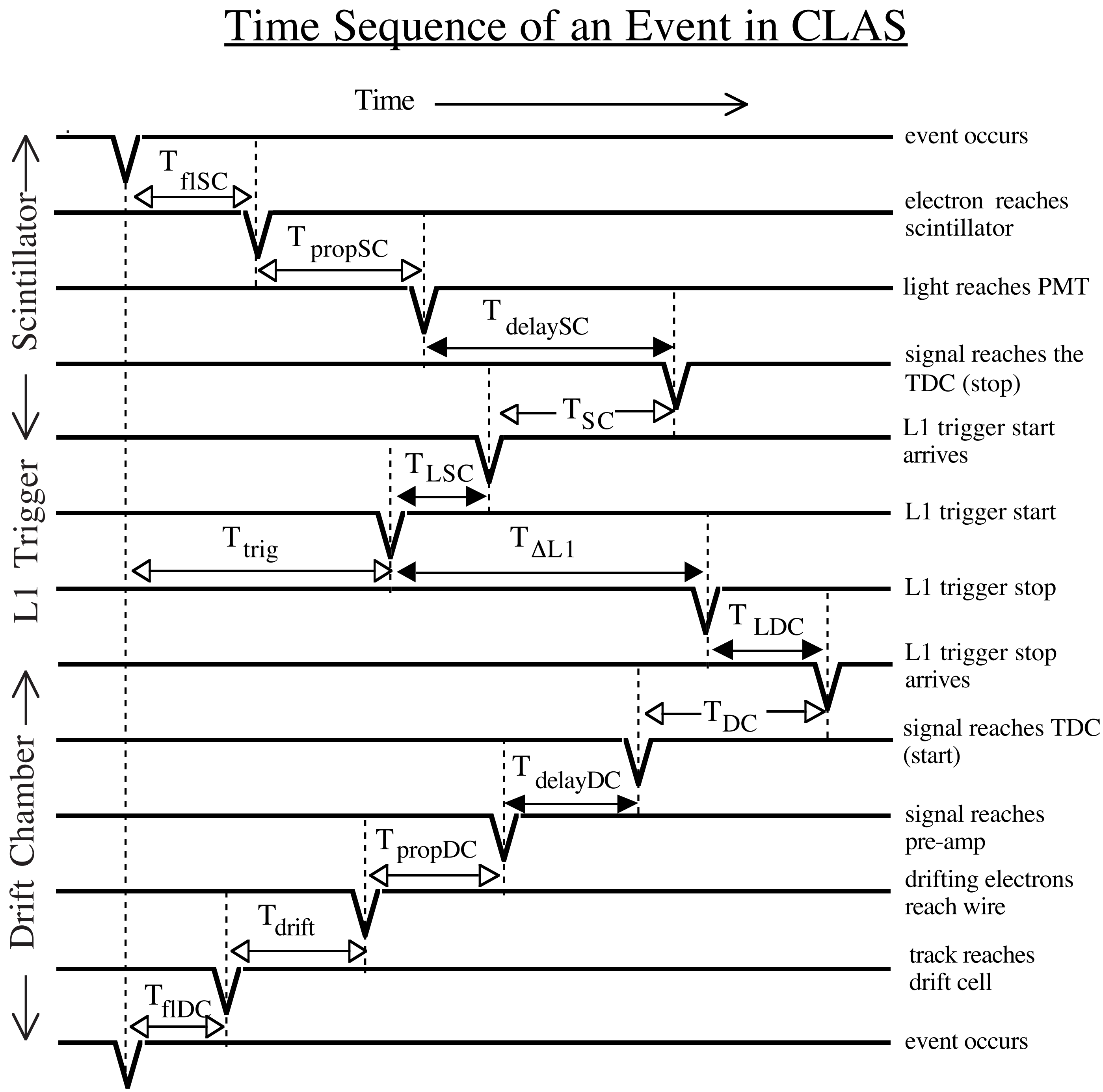

Figure 1. Schematic drawing of the time components of a CLAS event. The solid arrowheads mark time differences that are fixed from event to event. The open arrowheads mark time intervals that vary from event to event. The time intervals are NOT to scale.

that is measured by the scintillator TDCs.

$$(2) \qquad T_{SC} = T_{flSC} + T_{propSC} + T_{delaySC} - T_{trig} - T_{LSC} \qquad .$$

The pieces of Equation 2 are T_{flSC}, the flight time of the scattered particle to the scintillator; T_{propSC}, the propagation time along the scintillator; $T_{delaySC}$, the cable and electronic delay for the signal to reach the TDC stop T_{SC}, the measured time extracted from the scintillator TDC reading; and T_{LSC}, the cable delay from the L1 trigger to the scintillator TDC start. The quantities T_{flSC} and T_{propSC} are obtained from the track reconstruction. The quantities $T_{delaySC}$ and T_{LSC} are fixed calibration constants. The quantity T_{SC} is determined from the scintillator TDC reading.

Similarly, one can start at the bottom of Figure 1 and go up to find an equivalent expression for T_{trig} based on a drift chamber signal.

$$(3) \qquad T_{trig} = T_{flDC} + T_{drift} + T_{propDC} + T_{delayDC} + T_{DC} - T_{LDC} - T_{\Delta L1}$$

Equation 3 can be rearranged to give an expression for T_{DC} which is the quantity that is measured by the drift chamber TDCs.

$$(4) \qquad T_{DC} = T_{trig} + T_{LDC} + T_{\Delta L1} - (T_{flDC} + T_{drift} + T_{propDC} + T_{delayDC}) \qquad .$$

The components of Equation 3 are T_{flDC}, the time-of-flight of the scattered particle to a drift chamber cell; T_{drift} (the quantity of interest), the drift time in the cell; T_{propDC}, the time for the signal to propagate along the wire; $T_{delayDC}$, the time for the signal to go from the pre-amplifier to the drift chamber TDC start; T_{DC}, the measured time extracted from the drift chamber TDC reading; $T_{\Delta L1}$, the fixed time delay between the start and the stop from the Level 1 trigger; and T_{LDC}, the cable delay from the L1 trigger stop to the drift chamber TDC stop. The quantities T_{flDC} and T_{propDC} are obtained from the track reconstruction. The quantities $T_{delayDC}$, T_{LDC}, and $T_{\Delta L1}$ are fixed calibration constants. One can then equate Equations 1 and 2 and solve for T_{drift} to obtain the following result.

$$(3) \qquad \begin{aligned} T_{drift} = T_{flSC} + &T_{propSC} + T_{delaySC} - T_{SC} - T_{LSC} - \\ &(T_{flDC} + T_{propDC} + T_{delayDC} + T_{DC} - T_{LDC} - T_{\Delta L1}) \end{aligned}$$

Equation 3 displays the components necessary to calculate the drift time.

3. Analysis Outline and Drift Chamber Group Responsibilities

We now outline the steps in the analysis sequence of a typical CLAS event with emphasis on the software responsibilities of the drift chamber group. (1) The software is initialized by reading in analysis configuration data from the user, magnetic field configuration data, and geometry data. The drift chamber group's responsibilties during this phase are to maintain three sets of calibration constants. Those three sets are the ideal CLAS geometry described in Reference 2, the parameters needed to extract the distance-of-closest approach D_{ca} from the drift time T_{drift}, and the electronic and cable delays for each sense wire. (2) Next, the CLAS raw event buffer is read in and (3) initial pattern recognition is done to identify track segments in individual superlayers and collect these segments into clusters. (4) Tracking is performed without drift times in the drift chambers to identify the electron. Steps (3) and (4) are repeated for each sector to find the best electron track candidate. (5) Tracking is then done again with drift times. For each sense wire in a track the measured TDC reading is converted to a time and the components of the drift time in Equation 3 are calculated or read from the appropriate calibration data. The drift time T_{drift} is calculated, the left-right ambiguity of tracks is resolved and the drift distance calculated from T_{drift}. The drift chamber group's software responsiblities during this phase are to maintain the routine that calculates T_{DC} from the TDC reading and adds the fixed hardware delays $T_{delayDC}$ and T_{LDC}(see Equation 3). These delays are fixed from event to event. It is one of the calibration constants that will be determined during commissioning of the CLAS. We are also responsible for maintaining the algorithm that extracts the drift distance from T_{drift}. (6) Final fitting is tracking is performed to get the best-fit track and the distance-of-closest-approach of the fitted track to each sense wire is determined. Steps (5) and (6) are done for each of the remaining track candidates.

4. Drift Chamber Data Structures

We are now in a position to define the data structures that are needed for monitoring and calibration of the CLAS. These data will reside in an array or BOS bank as the need arises. The elements of the data structure are listed in Table 1 along with a description of each element.

Table 1. Drift Chamber Data Structures for Monitoring and Calibration

Variable	Description
POS_LYR	Position of the point where the track intersects a sense-wire layer. For the 0^{th} layer this would correspond to the x,y components at the target where z=0.

DIR_LYR	Three-component vector pointing in the direction of the track at the position in space where the track intersects a sense-wire layer, i.e., it is the track direction at the end point of the vector POS_LYR.
S	Path length of track to the point where the track intersects the sense-wire layer (real).
TOF_LYR	The flight time of the particle to POS_LYR.
DELTA_Y	Position of track along the wire.
ID_WIRE	Wire number in CLAS format.
DRIFT_TIME	Final result of full, drift-time analysis. See Equation 5.
DRIFT_DIST	Drift distance determined from the drift time.
DOCA	Distance-of-closest-approach determined from the reconstructed track.
SIGMA	Uncertainty in measured drift distance.
CHISQ	The χ^2 of the track (real).
STATUS	Represents status of wire in fit, *e.g.* if the wire was excluded or not (integer).

References

[1] 'Conceptual Design Report - Basic Experimental Equipment', CEBAF, April 13, 1990.

[2] 'CLAS Geometry Format', E.Burtin, *et al.*, CLAS-Note 95-008.

Time Sequence of an Event in CLAS