Drift Time Measurements in Limited Streamer Tubes

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Abstract

We have investigated the performances of drift time techniques applied to limited streamer tubes. A resolution of $\sim 150 \mu\text{m}$ in the coordinate across the wire is found and a way to solve the left-right ambiguity is presented.

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1. Introduction

Plastic limited streamer tubes^[1] (LST) are widely used in high energy physics in presence of low particles fluxes and when large sensitive areas are requested. Typical applications are large calorimetric devices and muon detectors.

The success of LST is primarily due to the easiness of construction and the possibility of using inductive read-out cathodes decoupled from the main tube structure, thus reducing the cost of the read-out system.

In most of the applications of LST's as position sensitive device, the coordinates are obtained using digital strips parallel, and eventually orthogonal, to the wires. The spatial resolution is then limited to $\sigma = 3$ mm by the wire pitch and the multihit effect, caused by the broadness of the induced signal on the strips.

A better determination of the position along the wire can be obtained by measuring the centroid of the charge induced on the orthogonal strips. This method, proposed by the UA1 collaboration ^[2], has an intrinsic resolution of less than $\sim 300 \mu\text{m}$ ^[3], but it is limited to $0.5 + 1.1$ mm due to systematic effects depending on alignment, calibration and algorithms used to determine the streamer position ^[3].

Such a method cannot be used for a high resolution space determination orthogonally to the wires. However, it has been shown ^[4] that the drift velocity of the electrons from the ionization point to very close to the wire, where the streamer starts, is practically saturated, so that the distance of the track from the wire can be inferred by the drift time.

We present here experimental results of a test where this method has been extended to a large tracking system and several practical solutions are discussed in order to use it as a high-resolution low-cost muon chambers system for the ZEUS ^[5] detector at HERA.

2. LST geometry, principles of operation and construction

The standard geometry of LST modules that we will adopt along this paper is described in fig. 1. The basic element of a module is an eight-fold extruded PVC profile, internal cell dimensions of $9 \times 9 \text{ mm}^2$, inserted in a plastic box; at the center of each cell a $100 \mu\text{m}$ diameter silvered copper-beryllium wire is stretched, supported every ≤ 47.5 cm. No graphite coated cover was put on the open PVC profile ("coverless" tubes). The module is completed with a small printed circuit holding the appropriate resistors that decouple them and two end-caps equipped with feed-through for gas and HV supply. The

cathode is the inner profile coated with a very thin layer (thickness $\leq 10 \mu\text{m}$) of graphite-based paint yielding an average resistivity of $100 \text{ K}\Omega/\square$. The LST's were operated with a gas mixture of Ar + Isobutane (25% + 75%) and a negative HV of 4.6 KV. The "streamer" mechanism is rather important for a good understanding of the drift in LST and we briefly sketch it in fig. 2 a,b,c: a) when a charged particle crosses a tube it ionizes the gas along its path creating a number of primary electron-ion pairs; b) while the ions move towards the cathode (graphite coating), the primary electrons drift in the direction of the wire, producing further ionization, moving with a velocity governed by the electric field experienced and by the gas mixture characteristics; c) the cloud of electrons reaches the anode and then the streamer occurs; the streamer can be understood as a low power discharge from the wire towards the cell borders. This particular discharge regime is located between the proportional mode and the Geiger mode.

The streamer phenomenon is characterized by a large electric signal in a short time (typical values: 50 mV on 50Ω load and 50 ns) resulting in the possibility of adopting a relatively simple and cheap electronics.

3. Drift time measurement

3.1 Test set-up

A test has been carried out at the CERN PS East Hall with the set-up described in fig. 3a. It consisted in a set of beam defining counters $B_1 \dots B_4$, that provided also the START to the TDC's, and 8 layers of LST chambers; to tag muons the B_4 counter was placed after 1 m of iron. The mechanical rigidity of each LST chamber was insured (fig. 3b) by an aluminium honeycomb plane, $1.5 \times 1.5 \text{ m}^2$ area, 3 cm thickness, onto which 10 groups of 8 LST were glued. The digital strips were then glued to the tubes on the side of the PVC profile. On the other side of the chamber, a layer of orthogonal strips with analog read-out was installed in order to record simultaneously the second coordinate. Each complete plane was finally mounted on a general frame able to support the total weight of the planes without deformations.

In addition to the digital read-out the wires outputs were amplified (amplification factor 3), discriminated (threshold 30 mV) and then sent to TDC modules with 8 wires ganged together in one TDC input in order to reduce the total number of channels; in this way, event per event, the digital information singles out the hit wire and the TDC value

gives the precise coordinate within that tube. Furthermore, to eliminate the possible confusion arising when two contiguous digital strips are present, the wires are OR-ed in an odd and even fashion (fig. 4a, b, c).

3.2 Results

Fig. 5a shows the row drift time in one LST; the total width is ~ 80 ns roughly corresponding to an average drift velocity of $50 \mu\text{m/ns}$. Before showing any figure for the resolution one has still to solve the left-right ambiguity problem inherent in any drift time measurement. A hint that a direct solution (before any tracking fit) exists comes from the well known observation that, event per event, the number of digital strips fired is not exactly one, but in a fraction of events ranging from 30% to 70% depending on the threshold, there are two digital strips present. It happens in fact that the second strip, when present, indicates the side of the wire where the streamer occurred. This was checked by us in a bench test, illustrated in fig. 5b, where a LST was equipped on one side by normal digital strips and on the opposite one by analog strips, parallel to the wires but displaced by half a cell. The center of gravity of the charge induced on the analog strips is shown in fig. 6a, where one can clearly observe a double peak structure on both sides of the wire, allowing an unambiguous assignment of the streamer side. Fig. 6b and 6c show the same distribution for events when 2 digital strips were present and the second one was respectively to the left or to the right w.r.t. the wire. It is evident that almost in 100% of the events that show 2 digital strips, the second one resolves the left-right ambiguity. For the remaining planes we rely on a global track fit. In a real detector, with many planes of LST, one can vary the threshold applied to the digital electronics in order to maximize the fraction of events having two strips fired.

Fig. 7 shows the space-time relationship, for a typical chamber, for events taken at the CERN test with the set-up described in figs. 3a and 3b. Tracks were fitted using all chambers and the left-right ambiguity was removed by the global fit wherever not possible by using the digital strips information within a single plane. The drift velocity assumed was $50 \mu\text{m/ns}$ under the hypothesis that the drift velocity, although being in principle a function of the electric field, is in reality sufficiently constant so that one can assume it to be exactly uniform all across the LST without any worsening of the spatial resolution. One can observe a very clear space-time relationship all across the tube and, by comparison with the LST sketch indicated in the bottom of the same figure one can observe the lack of events in the border region between two adjacent cells where a 1 mm

plastic spacer is. The superimposed line represents a constant drift velocity of $50 \mu\text{m/ns}$ with $t = 0 \text{ ns}$ on the wire. The deviations from the fitted tracks are shown in fig. 8a, indicating a resolution around $150 \mu\text{m}$. This figure is only weakly affected from uncertainties on the wire location because the beam spot was rather small covering only few centimetres along the wire. These results refer to tracks perpendicular to the LST chamber plane. We also checked the variation of the resolution by rotating the whole apparatus by 11° in the xz plane (see fig. 3); no effect on the resolution was observed.

These results were obtained by using standard high resolution TDC's, LRS 2229 250 ps bin width, but it is clear that a drift-chamber type of time resolution, i.e. around 1 ns, would not affect the result.

As mentioned in the introduction, we intend to use this method in the muon chambers for the ZEUS detector of HERA where we have wires as long as 10 m and, for inclined tracks, the difference in the coordinate along the wire at which a particle, within one event, crosses different LST's is as big as 2 metres; in that respect a possible limitation to this technique could come by the propagation velocity of signals along the wire that, if too high, could either impose eventually heavy corrections in the off-line analysis or spoil the resolution. We investigated this point by scanning a 5 m long LST with a radioactive source and comparing the time difference of the signals coming from the wire read-out and those from a pad located under the LST and following the source path. The resulting velocity of 0.25 m/ns , shown in fig. 8b, is sufficiently low that only a rough knowledge of the coordinate of the event along the wire ($\sim 1 \text{ m}$) will be needed in the final analysis to recover the full precision orthogonally to it.

4. Conclusions

We have proved that the drift-time technique using standard LST works and the intrinsic resolution can be pushed, with a fairly economic electronics, to the limit of the mechanical tolerance, i.e. around $200 \mu\text{m}$.

The time information could be obtained directly by reading the induced signals on longitudinal strips, but a more economic solution can be found with an hybrid configuration and namely: commercially available digital read-out of the longitudinal strips and wire read-out, for the time determination, on the OR of 8 wires, grouped in odd and even sequence to eliminate mis-assignments.

The left-right ambiguity can be partially solved within the same layer of LST by

using the second digital strip, if present, and relying on a global track fit for the other planes. This method is of course best suited where particle multiplicities are very low (i.e. muon chambers), otherwise the read-out of every single wire is compulsory.

With this technique, used in conjunction with the analog read-out for the coordinate along the wire, it is possible to obtain, within a single layer of LST, a high space resolution in both coordinates. This scheme will be applied for the large muon system in the ZEUS detector at HERA and we think that it will be very useful for similar detectors at the future supercolliders where resolution, easiness of construction and cost will be leading key-points.

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Figure captions

Fig. 1 - Standard LST geometry.

Fig. 2 - Streamer mechanism:

- a) gas ionization and electron-ion pairs creation;
- b) drift;
- c) streamer generation.

Fig. 3 - CERN test:

- a) general set-up;
- b) LST chamber.

Fig. 4 - Odd & Even signals from LST wires:

- a) the simplest case;
- b) signals from two strips;
- c) signals from two tubes.

Fig. 5 - a) row drift time, 2 ns bin width;
b) bench test set-up.

Fig. 6 - a) coordinate of streamer;
b) as a), 2 digital strips (left side);
c) as a), 2 digital strips (right side).

Fig. 7 - Space-time relationship; x: coordinate across LST (mm);
y: drift-time (ns)
full line: drift velocity of 50 $\mu\text{m}/\text{ns}$.

Fig. 8 - Residuals (40 μm bin).

Fig. 9 - Propagation velocity; broken line: 4 ns/m.

References

- [1] See for a review on principles and applications of LST:
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- [5] ZEUS Tech. Proposal, March 1986 (unpublished).

FIG. 1

(A)

(B)

(C)

FIG. 2

(A)

(B)

FIG. 3

FIG. 4

NB OF
EVENTS

(A)

(B)

FIG 5

FIG. 6

T
(NS)

FIG 7

FIG 8

FIG 9