DRIFT CHAMBER APPLICATION IN HIGH ENERGY PHYSICS*

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Summary

We review the use of drift chambers in the field of High Energy Physics: existing apparatus, plans and ... dreams. We comment especially on low cost large area drift chambers, use of pulse height information and high spatial resolution applications.

1. Introduction

After the pioneering work of Charkap et al.¹, several high energy physics groups got interested in drift chambers. Walenta and coworkers² especially have been building and actually using in experiment very simple drift chambers for more than 4 years. Their success and the recent results of Charkap, Sauli and coworkers³ on spatial resolution of similar devices, triggered a large number of studies and developments all around the world^{4,5,6,7}. We will not review in this paper the level of success and of understanding achieved in operating drift chambers since it is discussed by Walenta⁸ at this conference. We will concentrate on the applications to High Energy Physics.

There are basically three reasons for the attraction of drift chambers for High Energy physicists: In addition to properties similar to multiwire proportional counters,

- a) the small number of wires may allow to equip at relatively low cost large areas.
- b) it may also allow the use of pulse height information, an unrealistic possibility for large proportional chamber systems because of the number of channels involved.
- c) the interpolation between wires provides high spatial resolution devices ($\sigma = \pm 100 \mu\text{m}$).

We will examine these properties in turn.

2. Large area "low cost" drift chambers

Neutrino physics requires large size detectors and drift chambers are attractive. C. Rubbia and coworkers⁴ have built drift chambers $4\text{m} \times 4\text{m}$ with a sense wire spacing of 10 cm and total gap thickness of 5 cm. They adopted the very simple technique of Walenta et al.² only scaling up everything including the wires which have a diameter of 100 μm . Their chambers operate well enough for their purpose, giving a resolution better than $\pm 500 \mu\text{m}$. However they suffer from a lack of linearity of time to position relation (because the electric field in the gap is not high enough) and from very small pulses: the reason for this phenomenon⁹ is that although the mechanical dimensions have been scaled up, the mean free path of electrons and photons has not been changed: around a thick wire, the electric field is still large far from the wire and the avalanche size is limited much earlier than with a small wire by parasitic phenomena¹⁰. (Semi Geiger pulses with large width and large dead time). Moreover the field gradient being lower, for a given avalanche size, the induced pulse height across the loading resistance will be smaller.¹¹

Turley et al. at Saclay⁹ fought against these problems with chambers similar to Harvard ones and finally decreased the sense wire diameters and shaped the electric field in the gap.

May be then the proper way to equip large areas would be to use instead of the Walenta scheme², the Charkap-Sauli scheme³. The chambers will be thin, the cathodes may be made out of printed circuits. The advantages of higher pulse height, smaller thickness, linearity and good two particle resolution may justify the higher mechanical cost.

3. Use of Pulse Height Information

The use of pulse height information to measure the amount of

energy deposited by a charged particle in a detector, have received considerable interest recently, especially in connection with the very high energy accelerators. It may provide particle identification through the use of the relativistic ionization loss, energy measurement of an hadronic shower by "calorimetry", detection and measurement of photons and electrons in shower counters.

Drift chambers may allow to equip large volume with relatively high spatial resolution while maintaining the number of elements at a reasonable level.

3.1. Ionization

A first example of the usefulness of such devices is provided by the proposal of W. M. Allison et al.¹² for identifying high energy particles by ionization sampling. Fig. 1 shows a sketch of the apparatus they are planning to build, is essentially a giant drift chamber with very large drift length (2 m). The signals of the 330 sense wires provide as many simultaneous position and ionization measurements through measurement of time and pulse height. Preliminary results with small scale model seem encouraging.

Fig. 1. Proposed setup for ISIS.

3.2. Calorimetry

As an example of calorimetry application Fig. 2 shows the triangular drift chambers imagined by D. Nygren at Berkeley. Such devices which should be cheap to build since they require mainly sheet metal work would be included in a large size calorimeter mainly made of iron. For instance, in neutrino experiments, they will detect accurately muons (detecting large angle scatters along the track especially) and measure the energy of hadronic showers. In the latter case, comparison of the pulse height in two adjacent cells may provide spatial information, allowing with 2 chambers a rough determination of the direction of the showers.

Fig. 2. D. Nygren's triangular drift chamber.

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b) Can drift chambers operate with good resolution in relatively large magnetic field?

The answer is positive (up to 16 kG) in drift chamber using the Charpak-Sauli scheme¹ if the electric field is suitably tilted. A. Litke and the present author² have shown also that with moderate sense wire spacing (1.52 cm) accuracy better than 100 μ may be achieved at 15 kG, in chamber using Walenta scheme²

c) What is the two particle resolution?

At high energy in multiparticle spectrometers the two particle resolution is an important since projectile fragments are separated by only a few milliradians as in the reaction

F. Sauli has shown that in chambers with field shaping a 2 particle resolution of 1.3 mrad can be achieved.

d) Is pattern recognition possible?

Several factors make the pattern recognition problem difficult with drift chambers in multiparticle large aperture spectrometer. Left right ambiguity, the two-particle resolution and the rate effects. The CERN group have studied this problem^{1,2} simulating events in 5 super-modules of 6 drift chambers. They are organized in 2 groups of 3 chambers with wires at 0° and $\pm 10^\circ$ with respect to the magnetic field. The two groups are displaced with respect to each other by half a wire spacing (2.5 cm).

The first method of trying to reconstruct in each super module space points and then linking them has not a large enough efficiency. In the reaction given above only 90% of tracks are reconstructed properly giving a global efficiency of 65%. It is then necessary to work on projections and match afterwards projected tracks. This method works well but is rather long (100 ms of CDC 7600 per event). This is prohibitive in a large data rate experiment and the Omega group is planning to use drift chambers with the present spark chambers (Fig. 3). The latter will be used in pattern recognition while the former will give the high resolution needed. In the long run spark chambers will be replaced by proportional chambers.

4.3 Simultaneous Detection of Charged Particles and Photons at Storage Rings. The high spatial resolution of drift chambers

opens a very interesting field for High Energy Physics around storage rings such as the e^+e^- storage rings at DESY or SLAC (DORIS and SPEAR) and the ISR pp storage ring at CERN. There are many physical reasons to attempt to measure simultaneously charged particles and photons. Unfortunately good photon detectors (lead glass, sodium iodide) are expensive and the obvious solution of surrounding a large size magnet with photon detector was till now too expensive. The potential resolution of cylindrical drift chambers however allows to shrink considerably the charged particle detector and reduce therefore the volume of the photon detector. Fig. 6 shows three similar apparatus being built or planned respectively for DORIS, ISR and SPEAR.

The DORIS detector built by Heidelberg¹⁴ has no magnetic field and only moderate resolution drift chambers (100 MHz/clock). The longitudinal coordinate is measured with cathode strips and timing of cathode signals allows to pair longitudinal and azimuthal coordinates. The apparatus is being installed at DESY.

A more ambitious setup is being built at CERN for the ISR by the CERN-Columbia Rockefeller collaboration¹⁵. Cylindrical drift chambers with 5 cm sense wire spacing will operate in a 15 kG magnetic field. The Charpak scheme of field shaping is used and the longitudinal coordinate is obtained through simple delay line parallel to the sense wires. Resolution of 100 μ are hoped.

A rather similar device (MINIMAG) has been proposed by Berkeley for operation at SPEAR in early 1977. The magnetic field will be 5 to 10 kG, the resolution aimed for is 100 μ . The fact that the drift chambers will be used in the trigger and the repetition rate of the machine (780 ns) restrict the drift time to 200 ns (1 cm drift length) and this group is considering using Walenta's construction scheme. Longitudinal coordinate would be then measured with cathode strips.

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Fig. 5. Simultaneous detection of charged particles and photons. From left to right: Heidelberg setup, CERN, Columbia, Rockefeller apparatus and MINIMAG.

3.3 Photon Detectors

A challenge to high energy physicists is the detection of photons with good spatial and energy resolution and high efficiency. The few hundred MeV energy region especially is important for many applications such as physics around the e^+e^- storage rings^{14,15} and is challenging.

The obvious approach is to interleave converter and charged particle detector which will detect the conversion shower. However the experimentalist who wants good energy resolution is faced with the problem of the unmeasured energy loss in the converter, and is left schematically with two solutions. Either measure the energy loss in the converter itself for instance by making it out of lead glass ("active converter"¹⁶) or making many thin converters to limit the internal fluctuations and measuring the energy of the shower together with its position in the charge particle detector.

The latter method has been advocated by Willis and Radeka¹⁷ with the use of liquid Argon detectors. We would like to mention here similar proposals using drift chambers.

Sherwood Parker¹⁸ from Hawaii proposes to make a shower counter essentially by filling a ISIS type device with thin lead plate parallel to the drift of electrons. The electric field could be generated with a resistive coating of the plates. The e^+e^- of the shower may be measured accurately by usual peak detection methods.

A original proposal has been also made at this conference by A. P. Javonovs, R. J. Strubbs and G. Charpak¹⁹. The idea is to fill the drift space of a drift chamber with a solid matrix of lead. The sheets of lead are perpendicular to the drift of electrons and such drift occurs in holes. They may be etched at small enough spacing to limit the amount of matter a shower electron has to travel through before reaching a drift hole, to any desired value. The electric field in the drift hole is produced by a difference of potential between each lead layer. The electrons are collected in an ordinary two dimensional proportional chamber where position and pulse height are measured. Such design has the advantage of a high density (5 g/cm³ i.e. half of lead density) allowing to have about 15 radiation lengths with a 15 cm thick device and solve elegantly the mechanical problem of supporting thin lead plates. However it is semitransparent to photons parallel to drift holes.

Drift chambers devices of these kinds may offer photon detection with very good spatial resolution (of the order of 1 mm). We should not however forget their limitations:

- The Landau fluctuation is a gas are much larger than in a dense medium²⁰ and will limit the energy resolution.
 - It may be difficult to have a constant amplification at a few percent level along the sense wires.
- Liquid argon, in these two respects, may be better.

4. High Spatial Resolution Applications

The potential high spatial resolution of drift chambers make them attractive in many experiments.

4.1 High Energy Beams. An obvious application where very high resolution is needed, is high energy beam. Only small chambers are needed and many groups (CERN, BNL, LBL, NAL, Heidelberg etc. refs. 2 to 8 and private communications) have achieved resolution of 75 μ m to 100 μ m for drift length smaller than 1 cm.

In addition to providing a good measurement of the incident particles, drift chambers allow to implement very simply selection of a given angle of incidence or scattering detection with standard coincidence circuits (Charpak and Sauli, Atac).

However a troublesome problem may be the space charge effects seen at high intensity. F. Sauli² have observed a decrease of pulse height by a factor two at a density of 10^8 particles per second and per mm of wires. This figure is in good agreement with the intensity at which Makowski and the present author²¹ observed similar effects in ordinary proportional counters (although their interpretation was different). This seems to indicate that drift chambers are only worse as far as their wire spacing is bigger. An obvious solution for large intensity will be to decrease the wire spacing.

4.2 Large Aperture Spectrometers. While equipping small aperture spectrometers with high accuracy drift chamber is similar to equipping beams, large aperture spectrometers give rise to a completely new set of problems because of the dimensions and the number of wires involved. CERN plans for instance, to install in the Omega spectrometer drift chambers of 1.5x3m (Fig. 3).

Fig. 3. Proposed drift chamber setup in Omega spectrometer.

a) Can a 100 μ m - 150 μ m resolution be maintained?

The CERN group under the direction of F. Sauli has been studying systematically this problem. Large drift chambers (Fig. 4) have been built by A. Dalluge where all the dimensions are guaranteed within $\pm 20 \mu$ m. F. Sauli and coworkers have performed a systematic study of gas properties. An important consideration in a large drift chamber system is the stability of drift velocity since one cannot afford to calibrate extensively and frequently all the wires. This requires practically the use of gases with electron drift velocities fairly independent of the electric field and therefore of the mechanical imperfections of the chambers, the gas density and the temperature. The mixture of 67.2% Argon, 30.3% isobutane and 2.5% methylal used by Charpak and coworkers¹ have a saturated drift velocity above a field of 1.2 kV/cm.

Fig. 4. Large drift chambers built at CERN.

The CERN group have installed a chamber in the Omega spectrometer in order to study the long term stability and the resolution obtained in real running conditions. The results are being analyzed.

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