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DRIFT CHAMBER PERFORMANCE IN THE FIELD OF A SUPERCONDUCTING MAGNET: MEASUREMENT OF THE DRIFT ANGLE

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We present the results of the first measurements in a study of drift chamber performance in magnetic fields up to 6 tesla. The angle of the electron drift has been measured as a function of electric and magnetic field intensity.

I. Introduction

The next generation of high energy accelerators (ISABELLE, Energy Doubler/Saver, VBA, etc.) opens new regions of available energy and particle momenta. The need for ever stronger magnetic fields for track separation and momentum analysis is evident. Increasingly, physicists are resorting to large, high field superconducting magnets in their plans for the future. Especially at ISABELLE, where the measurement is made in the reaction center of mass frame, large solid angle detectors with high fields and track detection within the field are most attractive. The highest spatial resolutions are obtained using drift chambers. To date, however, no use has been made of such chambers in more than moderate fields.

Careful studies have been made by Charpak and coworkers[1,2,3] of drift chamber performance in magnetic fields up to 1.6 tesla. They have shown that by appropriately tilting the electric field which causes the electron drift, the Lorentz force due to the magnetic field can be compensated for, with no significant degradation of chamber resolution or efficiency. Most features of drift chamber performance in fields up to 2 tesla seem to be consistent with the classical theory of electrons in gases.[4,5] In higher fields, 3-5 tesla, there appears to be no data assuring the success of the drift chamber technique. We have therefore begun direct measurements of the various detector properties in the regime.

The most disturbing feature introduced by a strong local magnetic field occurs when a field component is parallel to the sense wire. The drifting electron swarm may then be swept away from the sensitive cell. The relationship between the pulse arrival time and the particle track position is strongly distorted and the chamber efficiency is reduced for all but the shortest drift spaces. The common technique for compensating for this electron deflection is to tilt the drift chamber electric field by an angle chosen for the particular drift field E_d and applied magnetic field parallel to the sense wire $B_{||}$. At typical values of $E_d = 1.5$ kv/cm and $B_{||} = 1.5$ tesla, for standard gas mixtures, the required tilt angle can be as large as 50^0.[3] In this report we present measurements of the drift angle θ_d for a range of values of E_d, and for $B_{||}$ up to 4.5 tesla.

Other features of drift chamber performance are affected by applied fields. Magnetic field components $\vec{B}_\perp$ orthogonal to the sense wire direction distort the drift trajectory along the sense wire coordinate, unless the magnetic field $\vec{B}_\perp$ is along the drift field direction $\vec{E}_d$. This may require the use of narrow angle stereo measurements of this coordinate, or offline corrections of the trajectory measurement.[3] The magnitude of the drift velocity is affected by the magnetic field, and at the extremely high fields under consideration, the onset of drift velocity saturation may be affected. We hope to study these properties of drift chambers in later studies.

II. The Drift Angle Chamber

A. In order to measure the drift angle induced by magnetic field components along the sense wire direction, a small test chamber was constructed. The chamber was cylindrical in shape and fit within the warm bore tube of an available superconducting solenoid with peak field ~6.5 tesla. The general method of measurement, however, follows the technique used by Charpak.[3]

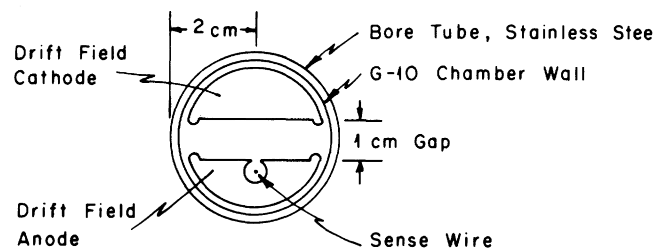

Figure 1 End view of the test drift chamber

Figure 1 shows the general construction of the chamber. A cylinder of G10 fiberglass epoxy approximately 8 cm long and 4 cm in diameter was used to house the chamber electrodes. The cylinder fit snugly within the bore tube of the superconducting solenoid. The bore tube served as the ground of the system for high voltage and signal and provided excellent electromagnetic shielding. The chamber electrodes were arranged to provide a drift space of a gap of 1 cm and a lateral uniform field region approximately 2.5 cm wide. The D-shaped drift electrodes shown were curved slightly at the outer edges. An analysis of the equipotential surfaces created by this geometry, using conducting Teledeltos paper, showed that this curvature compensated well for the fringe fields and provided the widest useable drift space. A narrow (.1 mm) slot in the face of the drift field anode exposed a smaller cylindrical

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cavity which contained a 20 micron thick gold-plated-tungsten sense wire. This cavity constituted a single-wire proportional counter. The sense wire was set at a potention $+V_s$ much more positive then the $+\frac{1}{2}V_d$ of the drift field anode. Figure 2 illustrates schematically how the chamber potentials were set.

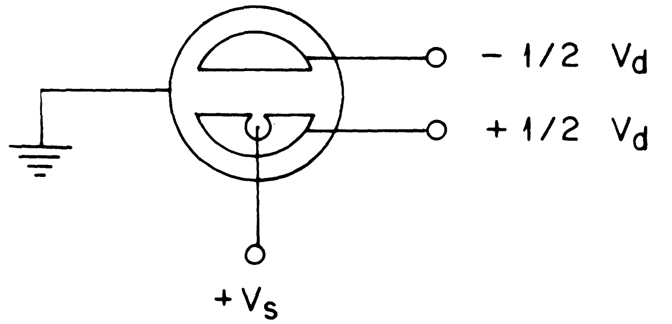

Figure 2 Potentials established in the test chamber

With this arrangement, in the absence of any magnetic field, only ionization generated directly in front of the slot in the drift anode could produce a signal on the sense wire. This might correspond to position 1 in Figure 3. A magnetic field parallel to the sense wire

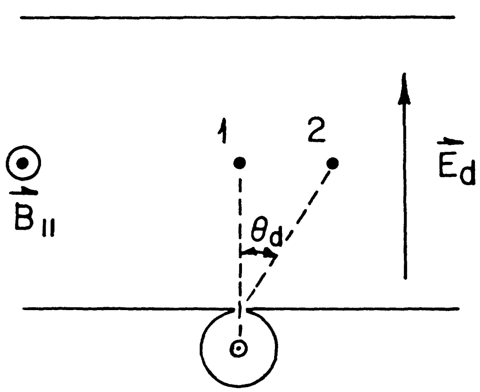

Figure 3 The drift angle

would produce a deflection of the drifting electron swarm. Signals on the sense wire would only appear from ionization at some position displaced by an amount determined by the drift velocity, B and E_d. In Figure 3 this would be position 2 and we define θ_d as the drift angle.

For a gas mixture which is relatively standard (67% argon, 30% isobutane, 3% methylal) the drift velocity is saturated for $E_d \gtrsim 1.5$ kv/cm. We have used this mixture so that our measurement can be compared to the previous work by Charpak.

A highly collimated 6 key x-ray source was fabricated by depositing 2 millicurie of Fe^{55} in solution into a glass vial with a 3 mm bore. The solvent was evaporated and the vial was mounted in a brass rod with a brass collimator. The source was mounted on a mechanical stage permitting accurate control of its position. The beam spot was moved across the chamber in intervals of .25 mm with a count rate 500/minute/mm^2. Figure 4 shows a typical measurement of the beam spot.

The chamber was plateaued using a scintillation counter telescope and the 1 MeV electrons from a Ruthenium source. Due to the narrow sensitive region above the slit in the anode, geometrical considerations limited the measured efficiency. In a more elaborate study external wire chambers could provide better beam definition. Nevertheless, the test chamber was plateaued for a variety of drift field settings. Figure 5 shows a

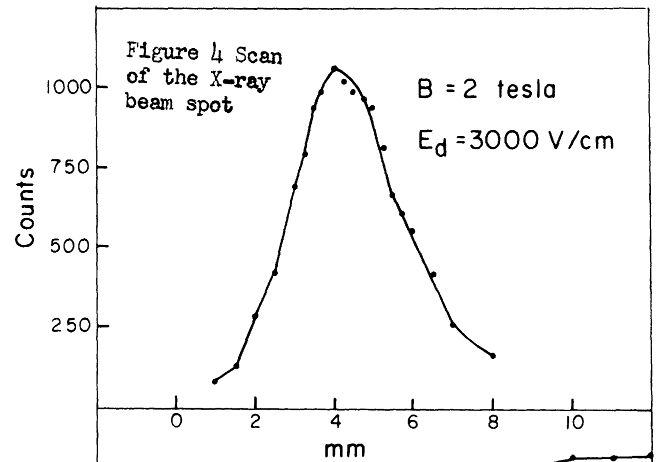

Figure 4 Scan of the X-ray beam spot

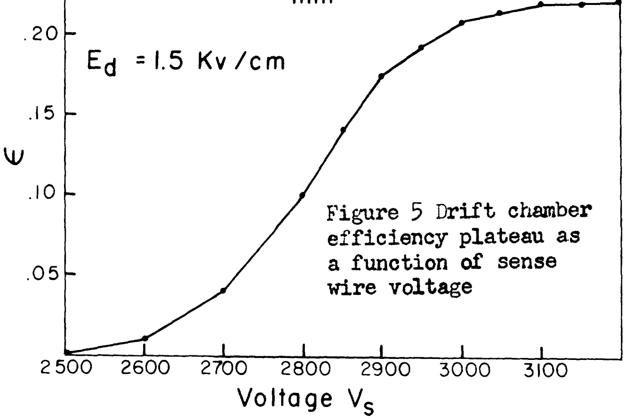

Figure 5 Drift chamber efficiency plateau as a function of sense wire voltage

typical plateau for E_d - 1.5 kv/cm as a function of sense wire voltage. For all measured conditions a good operating point was obtained. The chamber performance with the x-ray source was checked by measuring the counting rate as a function of V_s.

III. Measurements

Scans of the beam spot of the type shown in Figure 4 were made for a range of E_d from 1.5 kv/cm to 5.5 kv/cm and for B from 0 to 4.5 tesla. The drift velocity is expected[3] to be saturated at the value 5.2 cm/μs for fields below 1 tesla and for $E_d > 1.5$ kv/cm.

Figure 6 shows the results of Charpak's study below 1.6 tesla. For high values of E_d (above saturation of the drift velocity) the dependence of θ on B is linear and intercepts the origin. Note that replacement of the Argon in the chamber by Xenon reduces the measured drift angle by roughly a factor of 3. This suggests that at high magnetic fields if the electric potentials required to compensate for the drift angle are too high to be practical, a large chamber system might be made to work with Xenon. The disadvantage of Xenon is its extremely high cost of approximately \$15/liter at STP, necessitating a closed, recirculating chamber gas supply. The other properties of a drift chamber, drift velocity, stability under voltage and gas mixture drifts, and rate and multitrack resolution, would have to be studied with a Xenon mixture.

Figure 7 shows our data. The indicated errors are our best estimate of the systematic effects such as alignment and positioning accuracy, and uniformity of the drift field. The data points do exhibit a rough

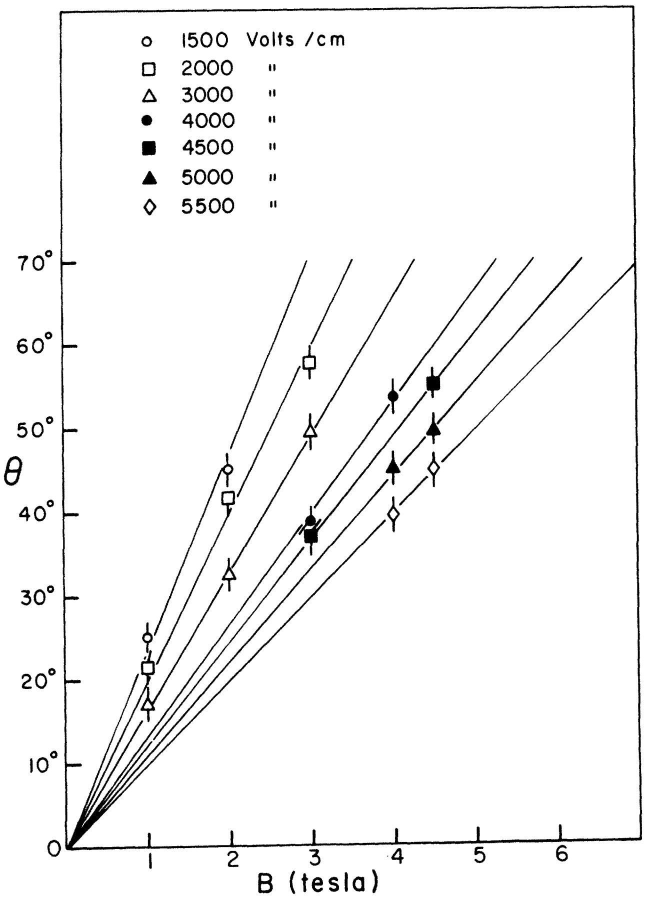

Figure 7 The measured drift angle as a function of the electric drift field and the magnetic field

linear dependence of θ on B, hinting that the drift velocity is still saturated. The points at 1 tesla agree well with the data of Charpak. Our profiles of the beam spot at high values of B and E_d show no gross broadening which might be indicative of dispersion due to loss of velocity saturation.

IV. Conclusions

It appears that even at the high fields of superconducting magnets (3-6 tesla) the drift angle induced by the Lorentz force $\vec{v} \times \vec{B}$ can be corrected for with tilted electric drift fields and/or the use of Xenon gas. At 3 tesla a drift field tilted at 45^0 with a magnitude of 3.5 kv/cm should restore normal operating conditions. At 4 tesla a 45^0 tilt field would have a magnitude 5 kv/cm. This probably approaches the maximum practical field for use in real chambers in an experimental situation. The advantages and difficulties of Xenon are obvious. We expect to extend our measurements to 6 tesla and to study the properties of Xenon gas mixtures, in the near future.

Clearly there remains much to be done before practical chambers can be employed in high magnetic fields. With a larger superconducting solenoid, a true prototype drift chamber with adjustable tilt field can be built and measurements of the drift velocity, resolution, the effect of varying gas and pressure can be carefully studied, as well as stability under voltage, rate and track multiplicity variations.

Acknowledgements

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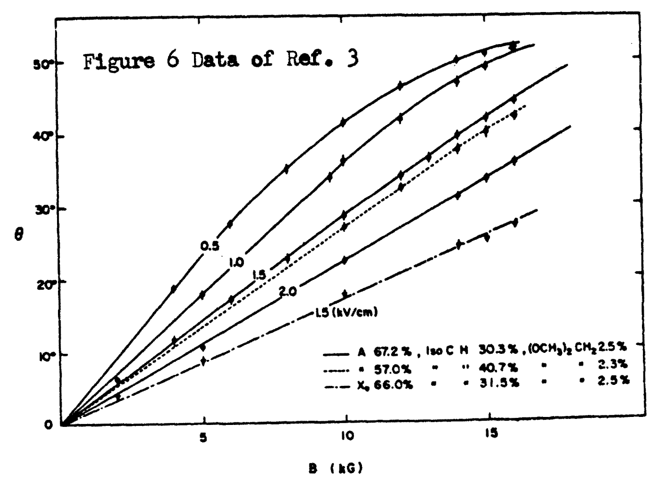

Figure 6 Data of Ref. 3