Measurements of Lorentz angles with a Micromegas detector in high transverse magnetic fields

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Abstract

We measured the Lorentz angles in an Argon +10% isobutane mixture using a Micromegas detector placed inside the CLAS-DVCS solenoid of Hall B at the Jefferson Laboratory. The primary goal of these tests was to validate Magboltz based simulations developed for the implementation of Micromegas bulk detectors in the Central Tracker of the future CLAS12 spectrometer. We used a UV Laser to extract electrons from the drift electrode of the detector. After amplification, the signal was collected on the readout strips. The difference of position observed between runs with and without magnetic field provided a direct measurement of the Lorentz angle. Scans in the drift electric field were performed for the first time in very high magnetic fields, up to 4.2 T, and a good agreement was observed with the Magboltz predictions.

Key words: Micro Pattern Gaseous Detectors, Micromegas, Magnetic field, Lorentz angle
PACS: 29.40.Cs, 29.40.Gx

1. Introduction

With the future upgrade in energy from 6 to 12 GeV of the Jefferson Laboratory, a significant part of the present equipment will be modified or changed. This is especially true for the Cebaf Large Angle Spectrometer (CLAS) [1] of Hall B, which will be upgraded to CLAS12, including in particular the construction of a Central Tracker that will be dedicated to the detection of hadrons at large angles (from 35 to 125°) and intermediate momenta (0.2 to 1.5 GeV/c). In the original design, this tracker is made of four double layers of Silicon strip detectors arranged in polygons around the beam line, but simulations performed at SPhN/Irfu showed that better tracking performance along with a significant reduction of the total cost could be achieved by replacing some of these layers by cylindrical, thin bulk Micromegas detectors [2, 3]. There is however a major difficulty related to the use of this detector in the CLAS12 environment, due to the presence of a 5 T solenoid field perpendicular to the electric field and normal to the strips in some of the detectors of the Central Tracker. As a consequence, the ionization electrons created in the conversion volume will drift with a large Lorentz angle, leading to a signal both shifted

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in position and spread over too many strips to be detected in a standard configuration. However, our simulations showed that an efficient working point can be obtained by i) decreasing the drift gap to approximatively 2 mm, ii) using a slow gas (typically Argon) and iii) increasing the drift electric field, thus decreasing the Lorentz angle down to around 20°. Since this value was crucial for our studies and only determined by Magboltz simulations [4] which have never been checked for such large magnetic field, we decided to validate these predictions with experimental measurements of the Lorentz angle at high magnetic fields. A first set of measurements up to 1.5 T were performed at CEA/Saclay using a warm dipole with a small Micromegas detector and are described in [5]. The rest of this article focuses on the magnetic field tests up to 4.2 T performed in the Hall B of Jefferson Lab.

2. Measurement Principle

The main issue with the measurement of the Lorentz angle inside a gaseous detector is to create primary electrons in a controlled way at a reproducable and precise location in the detector. Giomataris et al. first suggested and implemented a Laser-based extraction method for primary electrons [6], which solved this problem and allowed for Lorentz angle measurements. The principle is the following : a UV Laser hitting the drift electrode (composed of an aluminized Mylar) is used to extract electrons from the aluminum in a small area (typically a few tens of microns). These primary electrons drift just like the primary ionization electrons created by a particle, reach the mesh, and avalanche onto the strips as usual, giving a ”drift signal”. Figure 1 shows a transverse view of our experimental setup and electrons drifting in the problematic field setup: B collinear with the strips, and transverse to E. The quantity we extract is the so-called Lorentz angle, which is simply calculated from the shift observed on the strips and the distance between the drift and mesh electrodes. In our experiment, the Laser beam was strong enough to also extract electrons directly from the mesh, and therefore giving us a direct ”mesh signal”. One could calculate event-by-event the distance between the mesh and the drift signal, but the mesh signal is usually contained in one strip only and its position accuracy is very limited. Instead, we used a run without magnetic field to estimate the position of the Laser beam with a good accuracy.

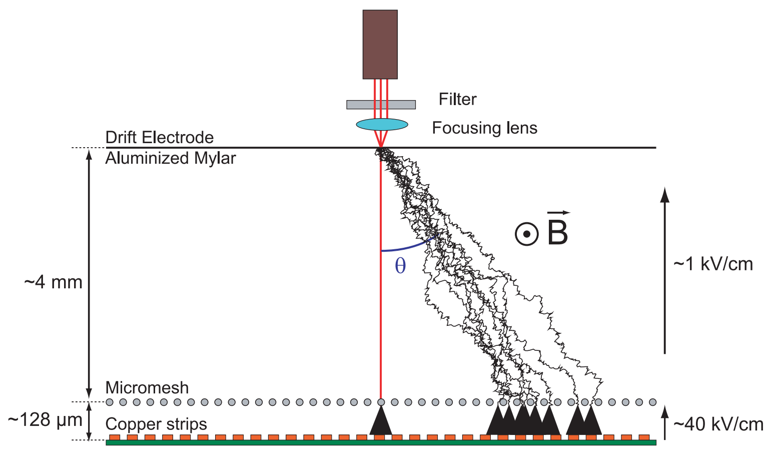

Figure 1: Schematic of the measurement principle of the Lorentz angle θ in a Micromegas detector.

3. Lorentz angle measurements in the CLAS-DVCS solenoid (Jefferson Lab)

3.1. Experimental Setup

The detector used for these tests was the second version of the Micromegas thin bulk made at CERN. Its dimensions were 500×115 mm^2 with 288×300 μm-wide strips at a 400 μm pitch. The 19 μm-thick, 500 LPI, stainless woven steel mesh was located at 128 μm from the strips. The drift electrode was an aluminized Mylar foil located at 3.85 mm from the mesh electrode. The detector was filled with a pre-mixed gas mixture of Argon 90% and iC4H10 10%. The magnetic field was generated by the supra-conducting DVCS magnet, able to deliver up to 4.7 T at the magnet center. The Laser used to extract primary electrons was a 20 Hz pulsed 355 nm UV Laser, with 50 μJ energy per 2.5 ns pulse. The optical system had to be customized in order to bring the UV Laser beam inside the solenoid magnet, leaving the Laser itself at very low magnetic field. This was performed using a set of 45° mirrors and a focusing lens close to the detector to focus a spot on the drift electrode. A schematic of the Jefferson Lab setup is shown on Figure 2.

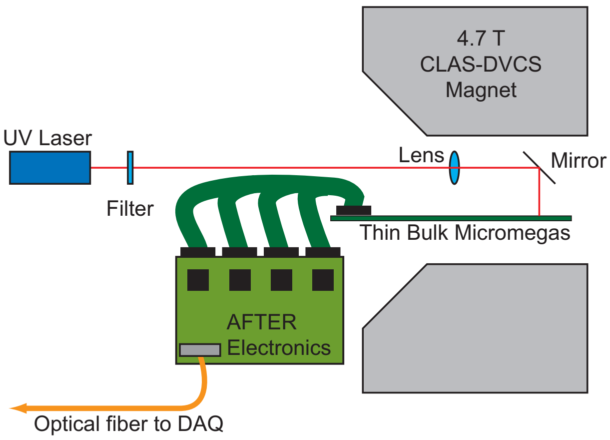

Figure 2: Schematic of the setup at Jefferson Lab. The Laser was actually located off-center with respect to the magnet axis using another 45° mirror, in order to minimize the magnetic field intensity at the Laser.

We used AFTER chips [7] as front-end electronics for these tests, in order to accommodate the large number of strips. The detector was connected to the electronics card by 4 flexible 80 cm-long circuit boards. The DAQ software was the test software from the T2K collaboration which uses the same front end electronics for their Micromegas TPC. The output was a binary file which was analyzed offline using a ROOT-based analysis software. The typical output of our offline analysis was a charge distribution as a function of the strip number as shown on Figure 3 for different magnetic and electric field settings.

3.2. Data analysis

Our main observable is the Lorentz angle as previously discussed. In order to calculate this value, we use the histogram of the average position of the drift signal. Two such distributions are shown on Figure 4, for 0 T and 2.8 T respectively. As expected, the distribution is much wider for the high field value. The Lorentz angle is then deduced from the differences of the central value of the fitted Gaussians between the 0 T run and the non-zero run using the following formula:

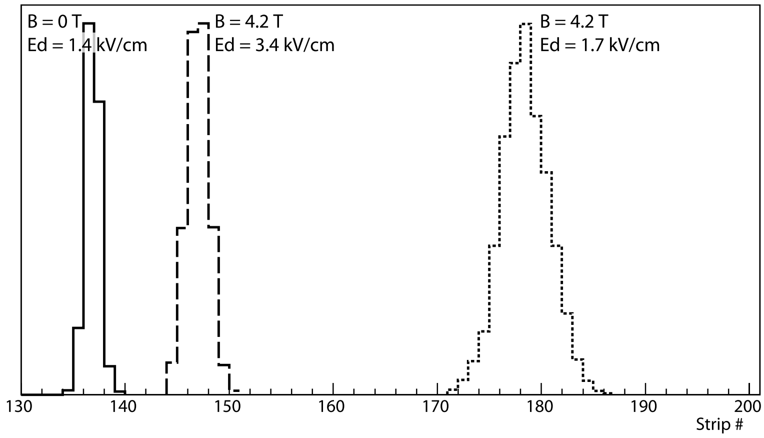

Figure 3: Charge received by each strip for 0 T (left, solid line), 4.2 T with regular drift field setting (right, dotted line) and 4.2 T with optimized drift field setting (middle, dashed line).

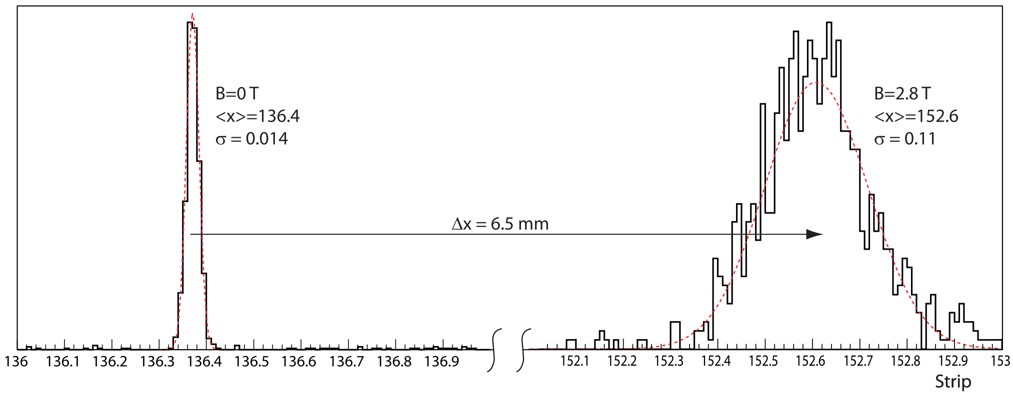

Figure 4: Average position of the drift signal calculated event-by-event for 0 T (left) and 2.8 T (right) for the same drift field.

$$\theta_{Lorentz} = \arctan\left(\frac{x_{drift} - x_0}{3.85\ mm}\right). \tag{1}$$

Thanks to the AFTER electronics, the full ion signal is pre-amplified, shaped and then digitized as a function of time for each strip. This is especially useful to take care of the pedestal subtraction which can be done with part of the time window, event-by-event. The integrated signal over a certain time window around the pulse gives us the recorded charge.

3.3. Results

Many measurements were performed at 1.4, 2.8 and 4.2 T, for different values of the drift high voltage (corresponding to electric fields between 40 and 700 V/mm). A potentially large uncertainty in the determination of the Lorentz angle comes from the drift electrode sag that modifies the drift gap. This sag was therefore measured precisely, leading to an error on the drift gap better than 100 μm. The error on the drift and mesh HV is of the order of 1 V, and is thus negligible.

We then compared the measurements with the predictions from the Magboltz program. The simulations take into account a small component of the magnetic field that was parallel to E, as the detector was not exactly at the center of the solenoid. Due to a precise survey of the position of the detector in the magnet, as well as the very good correspondence between the solenoid current and the magnetic field, the relative uncertainty on the magnetic field used in the data is less than 3% and therefore we do not show the associated error bands. Figure 5 shows that our data are well reproduced by Magboltz, and provide the first test of this program at such high magnetic fields. Moreover, it shows that Lorentz angles as small as 17° can be achieved at 4.2 T, which is very close to the working point required for the CLAS12 Micromegas, *i.e.* around 20° at 5 T.

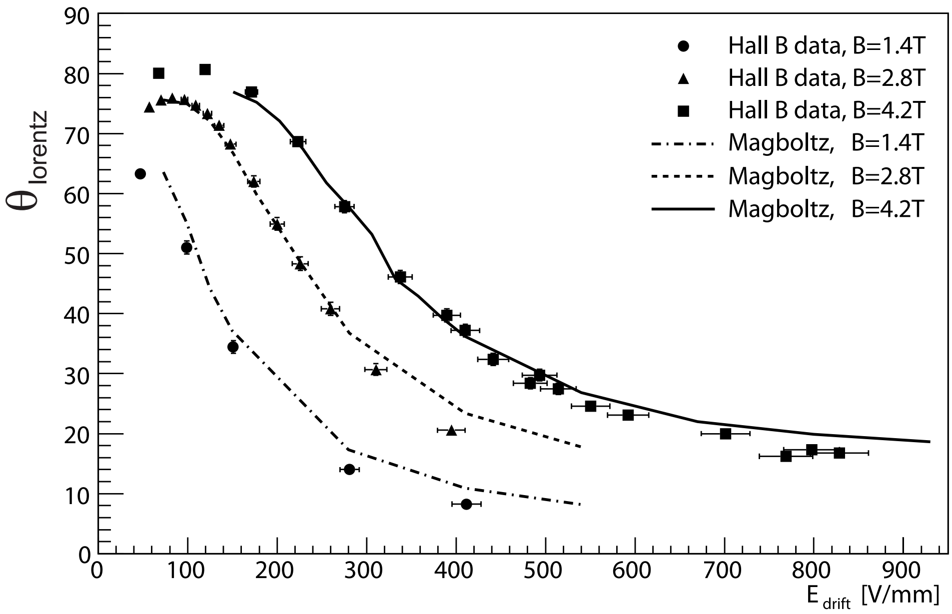

Figure 5: Lorentz angle versus electric field for a magnetic field going up to 4.2 T.

4. Conclusion

We presented measurements of the Lorentz angle in Argon isobutane mixture in magnetic fields up to 4.2 T. The results are in good agreement with Magboltz predictions, which were never checked for such high fields. They also strongly suggest the possibility to lower the Lorentz angle down to 20° in the 5 T CLAS12 environment, *i.e.* to reach the working point required by our simulations to achieve good tracking performance. Further tests made with cosmic rays without magnetic field indicated that the micro-mesh electronic transparency is decreased by around 50% in these conditions, but this results in an efficiency loss of a few percents only. Additional tests will soon be performed with hadron beams, to estimate the sparking rate of our detectors in the required field configuration.

5. Acknowledgments

We wish to thank I. Giomataris and J. Pouthas for their advice and many fruitful discussions, as well as R. Veenhof for his guidance for the simulations. We are grateful to the Jefferson Lab Hall B technical staff for their help setting up the magnetic field test bench in a very short time. This work was funded by French Agence Nationale pour la Recherche contract No. `ANR-07-BLAN-0338`.

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