Drift Chamber Performance as a Function of Magnetic Field

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Abstract:

We are designing drift chambers to provide tracking for a large acceptance detector at CEBAF. The detector is based on a superconducting toroidal magnet, and the chambers must achieve good spatial resolution in a non-uniform magnetic field. We conducted cosmic ray tests at Brookhaven on a small prototype chamber situated within a large gap magnet. We determined the performance characteristics as a function of the strength of the magnetic field and its direction relative to the wire direction. We have achieved spatial resolutions better than 180\(\mu\)m for field strengths up to 1.5 Tesla and angles (between wire and field direction) ranging from 0° to 30°.

Experimental Description and Summary of Results

The CEBAF Large Acceptance Spectrometer (CLAS) is built around a superconducting toroidal magnet which provides a non-uniform B field with the highest \(\int B \cdot dl\) values at forward angles. Some of the tracking chambers will operate in a region where the magnetic field strength varies between 0.5 and 1.5 Tesla, and the field direction relative to the wire will also vary between 0° and 30°. Since the B field affects the electron drift velocity, it is vital for us to understand this dependance in order to achieve good spatial resolution.

The CLAS drift chambers will have an hexagonal cell structure in which each sense wire is surrounded by six field wires; the sense and field wire diameters are 20 and 140\(\mu\)m, respectively. In the prototype, the wires were arranged in six layers of six wires each, for a total of 36, of which 32 were instrumented. The chamber was situated within the gap of the 48D48 magnet located in the D line of the AGS at Brookhaven. A scintillator telescope provided the trigger when a cosmic ray penetrated the chamber. We operated the chamber at 2550 V, with the discriminator level set to 20mV resulting in a greater than 99% efficiency of recording at least one hit from each penetrated layer. The bulk of the study was done with a pre-mixed argon ethane mixture of ratio 50:50 by volume. For a portion of the running, this mixture was diluted with helium to achieve a 60:20:20 mixture of helium, argon and ethane. We took data at 16 different combinations of magnetic field
strength and direction with respect to the wires' direction: $B = 0, 0.5, 1.0$ and $1.5$ Tesla and angles of $0, 10, 20$ and $30^\circ$.

For each scintillator trigger, we recorded the drift time from each of the chamber wires. The time was converted to a distance from the wire using an empirical function, and tracks were reconstructed by performing a weighted least-squares fit to the hit positions. Figure 1 shows a scatter plot of electron drift time as a function of the distance of closest approach of the reconstructed track for $B = 0$ and $B = 1.5$ Tesla. Note that drift times are increased substantially in the presence of magnetic field. Due to the hexagonal shape of the drift cell the time recorded on a wire depends on the angle of the track as well as on the distance of closest approach of the track to the wire. For $B = 0$, the minimum and maximum drift distances for a given drift time correspond to track angles of $0^\circ$ and $30^\circ$, respectively; while for $B = 1.5$ T, these angles are $-17^\circ$ and $13^\circ$. The dashed lines in Figure 1 are obtained from empirical fits to tracks whose angle was within $\pm 2.5^\circ$ of the denoted angle. The drift-time function for intermediate angles are obtained by interpolation.

In Figure 2 the drift time for a particular distance between wire and track is plotted as a function of $B$ field strength. The upper curve is for a distance of 8 mm; the lower corresponds to 4 mm. The drift time generally increases with increasing $B$ field, but the effect is larger for a larger drift distance. The "X" symbols on the plot (joined by the dotted curve) are for the case of a $30^\circ$ angle between field and wire direction. We observe that the non-parallel orientation of the magnetic field results in a small modification of the drift times of the electrons, which becomes significant only at large drift distances and high $B$ fields.

Residuals were formed by subtracting the distance as calculated according to the wire's drift time ($D_{wire}$) from the distance between track and wire ($D_{track}$) as calculated from the track parameters. The standard deviation of the residual distribution provides a measure of the spatial resolution for our chamber. The resolution is plotted in Figure 3 for various distances between track and wire. As expected, at large distances the resolution deteriorates, and the effect is increased for the $B = 1.5$ T case. However, we were able to achieve resolutions better than $180 \mu m$ for all $B$ fields and all orientations of the $B$ field direction.
Figure 1: Distance of closest approach of the reconstructed track to the wire, plotted versus the recorded time for that wire, for all angles of track incidence. The dashed curves are obtained from empirical fits to the data from tracks whose angles are limited to $\pm 2.5^\circ$ about the indicated angle.
Figure 2: The recorded drift times from wires for which the distance of closest approach of the track to the wire was 0.4 cm (lower curve) or 0.8 cm. The data are plotted versus magnetic field strength. Note that there are two sets of data: one for $B$ parallel to the wires; the other for $B$ oriented at 30° relative to the wire direction.
Figure 3: The rms residual between the position at a wire layer as calculated from the fitted track and the position as determined from the recorded time from the wire in question; i.e. the chamber's spatial resolution plotted versus distance of closest approach of the track to the wire.