Measuring Distortions in a TPC with Photoelectrons

Dean Karlen

University of Victoria and TRIUMF
Canada

In order to reach the desired momentum resolution with the large TPCs proposed for the ILC detectors it will be necessary to measure and correct distortions of the electron drift, particularly that due to non-uniform magnetic fields. This paper presents a proposal for using photoelectrons generated at the central cathode to provide critical information for distortion corrections.

1 Introduction

The large TPCs proposed to perform the central tracking for the ILC detectors will be very sensitive to non-uniformities in the electric and magnetic fields because of the long drift distance for the electrons. When operated with a fast gas in a strong magnetic field, the electrons will move nearly parallel to the magnetic field lines which reduces any distortions from electric field non-uniformities while increasing the sensitivity to non-uniform magnetic fields. With the finite beam crossing angle for the ILC, it is expected that a so-called anti-DID field will be introduced to reduce the background from low energy particles entering the detector. The effect of this non-uniform field component needs to be very well understood and corrected for, in order to attain the desired momentum resolution for the TPCs.

This paper presents a proposal for using photoelectrons as a controlled and reproducible pattern of electrons with which to monitor all aspects of electron transport in the TPC, including drift velocity, diffusion, gas gain, and the distortions from straight line paths arising from electric and magnetic field non-uniformities and from positive ion effects.

2 Producing photoelectrons

The proposed approach to produce a pattern of photoelectrons involves placing a set of aluminum elements on the copper surface of the central cathode. By flashing regions of the central cathode with a diffuse pulse of 266 nm wavelength light, photoelectrons are emitted from the aluminum and not the copper, due to the different work functions of those two metals. The aluminum pattern would be accurately surveyed during the central cathode construction, allowing for absolute measurements of the transverse displacements of the drifting electrons. This technique was used in the STAR TPC and will be used in the T2K TPCs that are now under construction [1].

For the test pattern to be useful to help empirically correct distortions that arise from imprecise knowledge of the fields or from positive ions, it is important to consider the ambiguities in solving the inverse problem: given the known positions of the test-pattern, and images from the device, determine the transverse displacements that electron clouds experience. If the test pattern consists only of long strips to mimic tracks, as was done in the STAR TPC, it is not possible to determine these displacements, as illustrated in Figure 1.

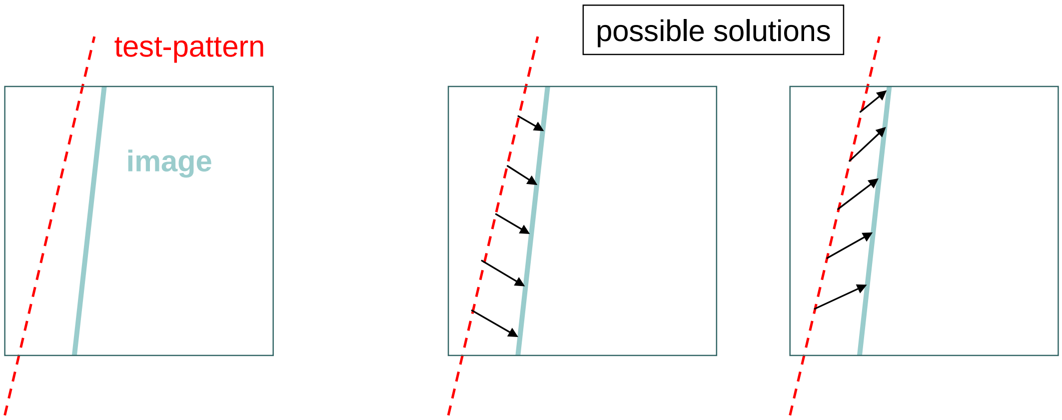

Figure 1. The left figure shows the test pattern projected onto the endplate and an observed image in the case of a large distortion in the drift lines of the electrons. On the right are shown two possible solutions that can produce the observed effect to illustrate the ambiguity that arises when using strips as test patterns.

To deduce the transverse displacements of the electron clouds, a pattern of dots should be used rather than lines. In order for the same system to also measure the diffusion constant for the gas, a few line patterns need to be incorporated, so that the same method as for tracks produced by traversing charged particles can be used.[2]

3 Demonstration of the system

As part of the tests for the T2K TPC design, this type of photoelectron calibration system was incorporated into the large T2K prototype TPC built in Canada in 2005. The test pattern consists of lines only, with thin aluminum tape applied manually and cut into 2,3, and 4 mm wide strips. Two contrast materials for central cathode surface were used, copper and carbon loaded kapton (the latter being the STAR design). In early 2007, a yag laser was acquired to test the photoelectron system. The UV light was introduced through the TPC endplate through a fibre terminated by two small lenses to defocus the light over the entire central cathode. The aluminum pattern and one of the first observed images is shown in Figure 2.

The jtpc analysis package was used to fit the track parameters for each strip separately. With laser images taken every second, it is possible to monitor the drift velocity at the precision of about 0.01% every few minutes. At the same time the diffusion constant and relative gain can both be monitored at the precision of about 1%.

The amplitude observed for any set of pads is seen to fluctuate by more than 10% from one laser event to the next. Power meters confirm that the pulse to pulse energy from the laser has a standard deviation of about 3%. The observed fluctuations can be attributed to the photoelectron production itself, which should follow a Poisson distribution. In fact, the variance is found to be proportional to amplitude, as expected for a Poisson distribution, and therefore the measure of variance and amplitude allows a direct estimate of the absolute gain, as shown in Figure 3.

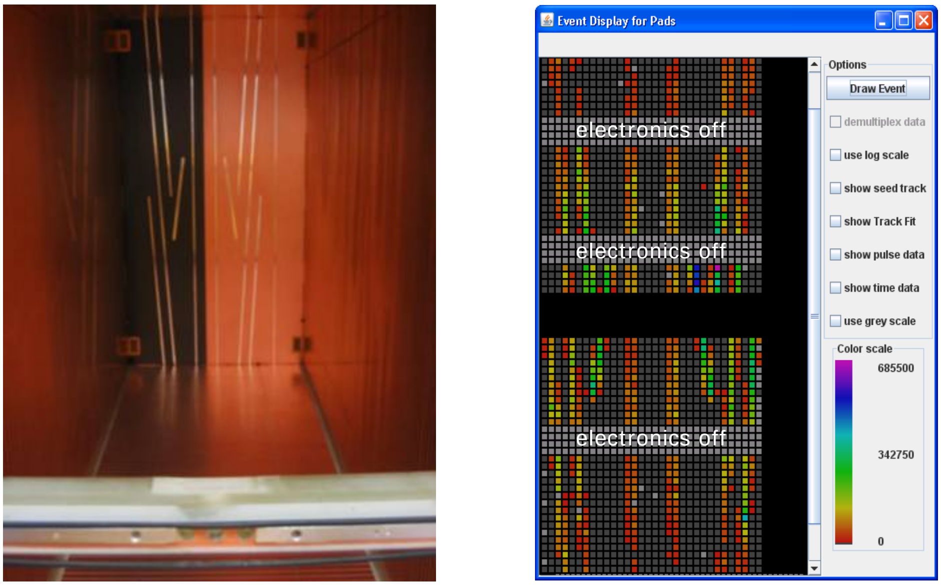

Figure 2. The photograph on the left shows a view inside the T2K prototype TPC built in Canada in 2005. The central cathode surface on the left is carbon loaded kapton, and copper on the right. The aluminum strips are clearly visible. On the right is an event display, showing the amplitude of the signals on the readout pads after a single flash of the UV laser.

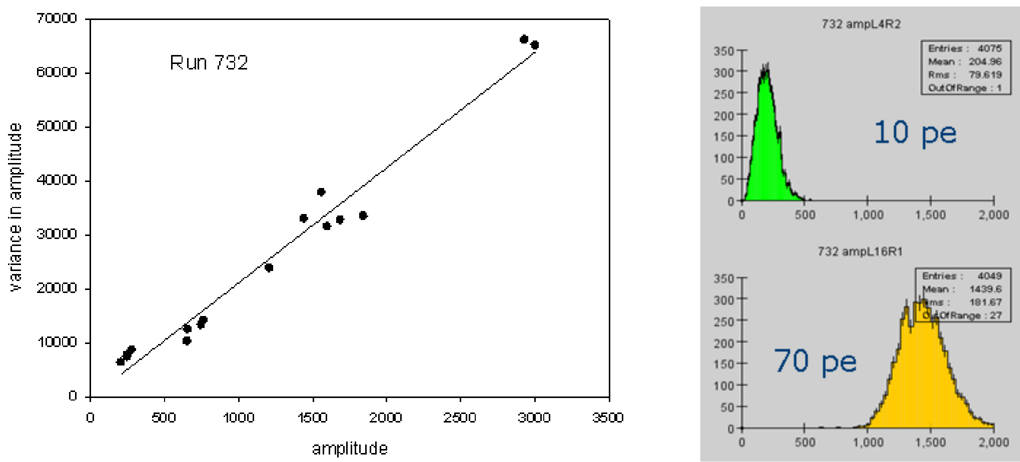

Figure 3. On the left is shown the observed relation between variance and amplitude for different sets of pads from laser events. This appears to be linear as expected for a Poisson process, thereby allowing for a direct estimate of the absolute gain of the system. On the right are shown the distribution of amplitudes for two selected pad groups and the estimated mean number of photoelectrons responsible for the signals.

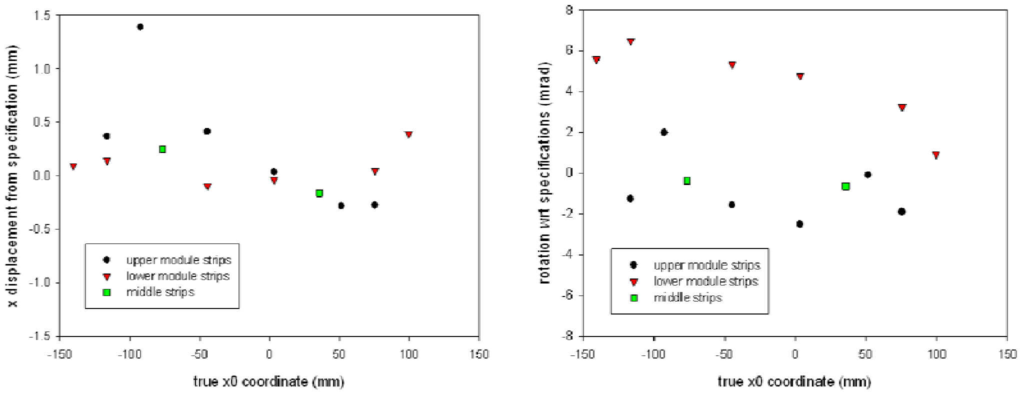

Figure 4. On the left is shown the difference between the specified and measured horizontal coordinates for the aluminum strips at the centre line of the TPC. The right figure shows the difference between the specified and measured azimuthal angles of the strips.

The track parameters for the horizontal coordinate (at the vertical center of the TPC) and the azimuthal angle for each strip pattern are compared to the specified locations for the strips in Figure 4. The horizontal displacements are seen to be all within 0.5 mm apart from one strip. There appears to be an effective rotation for the images in the lower module. When incorrect field cage potentials are applied, distortions greater than 10 mm are observed.

4 Considerations for the ILC TPC

For the ILC TPC photoelectron calibration system, a combination of dots and some radial (or nearly radial) strips should be applied to the central cathode. Dots of radius 1 mm produce an electron cloud with transverse standard deviation of 0.5 mm, allowing for measurements of displacements with precision of about 50 μm with just a few light pulses. Some gaps must be designed into the endplate readout to allow for the source of UV light to enter. This can be done with a few radial gaps – so that the azimuthal acceptance is uniform around the TPC. The system will require that the light intensity not vary across the surface of a dot by more than about 3%. The same specification is necessary for the knowledge of the relative gains from one pad to the next. A 3% difference results in a systematic shift of about 40 μm. In order to verify the utility of this system for the high precision requirements of the ILC TPC, we propose to install a photoelectron calibration system in the large prototype currently being designed by the LCTPC collaboration. Two fibers entering the endplate next to the readout modules will allow most of the central cathode to be exposed.

5 References

[1] T2K TPC Technical design report, T2K TPC collaboration, January 2007.
[2] D. Karlen, G. Rosenbaum, P. Poffenberger, Nucl. Inst. Meth. A555 (2005) 80.