it helps prevent the chamber from aging as opposed to organic gases (i.e. hydrocarbons). Organic quenchers, which dissociate after photon radiation, recombine to form polymers that accumulate on the wires leading to charge buildup and therefore, continuous discharging.

4.3 Wire planes

The wire frames are large printed circuit boards on G10/FR4 laminate material. The dimension of the active area for the first, smaller chamber is 140 cm x 35 cm and contains 141 signal and field wires for the U(V) plane and 142 wires for the X plane. The larger frames which will be used to assemble chambers 2 and 3 have an active area dimension of 200 cm x 50 cm and contain 200 signal and field wires for the U(V) plane and 202 wires for the X plane. Each signal wire is dedicated to its own electrical channel output whereas the field wires are all connected to a common channel for high voltage connection. The layout of the frames are located in the Appendix.

4.3.1 Wire Stringing

Two different types of wires are used for the drift chamber. The signal (anode) wires are 25 μm diameter gold-plated tungsten and the field wires are 90 μm diameter copper-beryllium (98.1% Cu, 1.8% Be). Signal and field wires are strung alternately 5 mm apart. The signal wires are sensor wires which register hits, not by charge accumulation on the wire, but by induction caused by the movement of electrons and ions toward the sense wire and cathode plane respectively [24]. The field wires serve their purpose by shaping the electric field in a way to optimize the electron's drift toward the anode wire. Thus, the field wires are not necessarily held at the

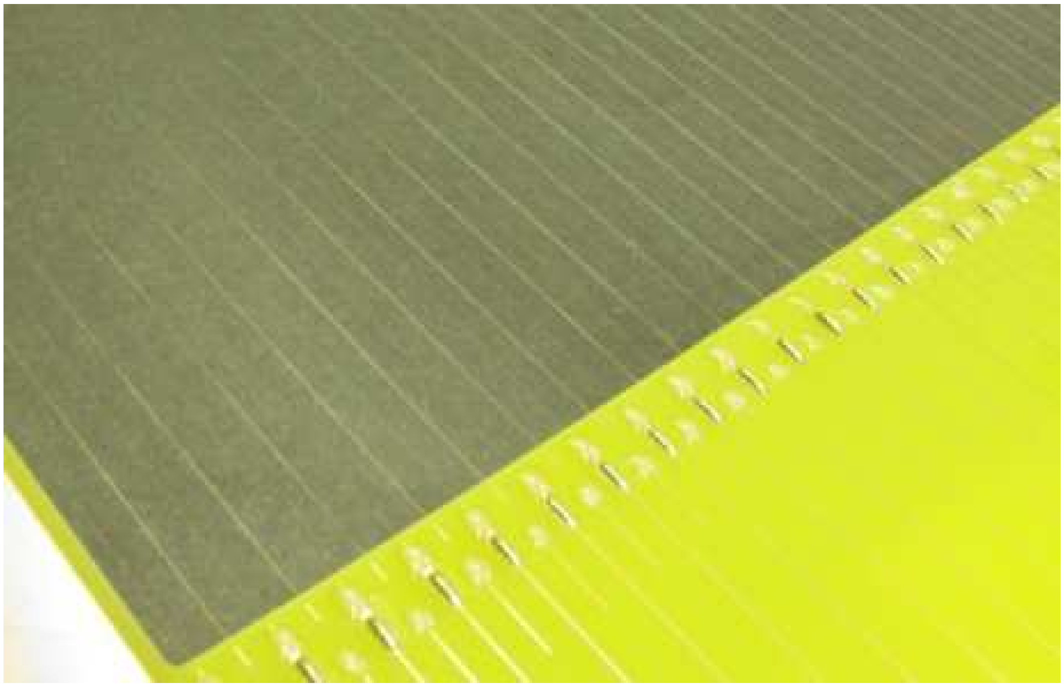

Figure 4.5: Closeup view of the wire/frame contact point. The circular blob is the epoxy which secures the wires on the frame.

same potential as the cathode planes are.

A new method that uses a pair of precision jigs to help guide the wires was developed to string the wires of these chambers. Before the wires are strung, the frame must be prepared and clamped down on the table. The frames must lay flat on the table so that the tension of the wires are uniform. Thus the only part of the frame where it comes in contact with the wires is at the electrical connection pads right at the edge of the active window (Fig 4.5). This region usually is raised to the necessary height by adjusting a variable screw, which is attached to the table, underneath the frame.

The next step in preparing to string is to align the jigs (Fig. 4.6). The jig consists of a set of pins used to guide the wire while stringing and a set of screws (nylon washers are placed underneath the screw to prevent cutting or tightening the wire) to keep them fixed relative to the wire plane. These pins and screws are attached on

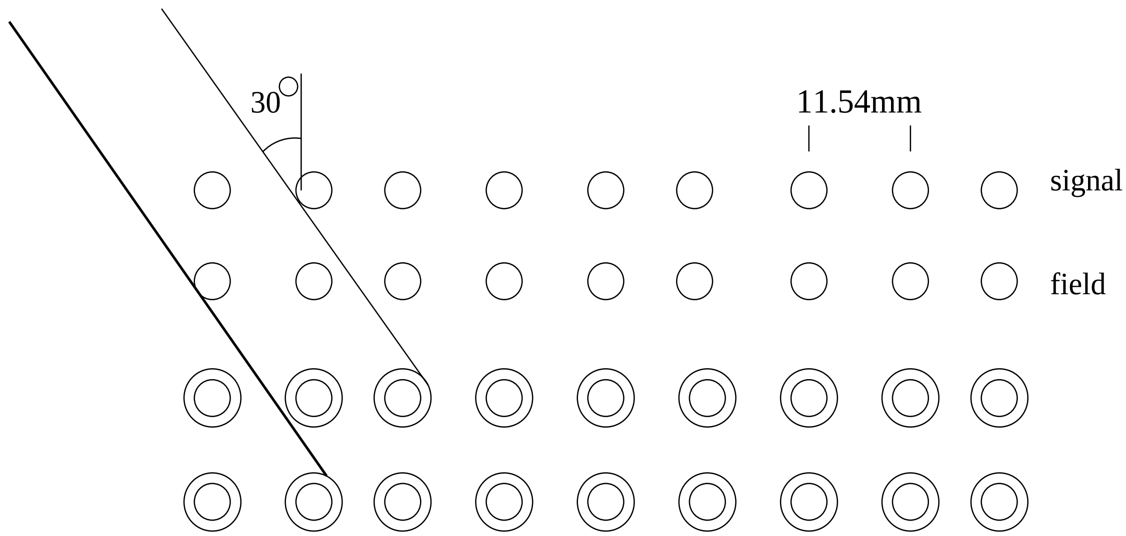

Figure 4.6: Illustration of the aluminum jig (for the U(V) frames). The top two rows consist or dowel pins 3.17 mm in diameter with the intent of placement. The bottom two rows consist of screws with each row dedicated to secure each type of wire. The different width lines correspond to the signal and field wires.

an aluminum railing which the railing can easily shift along the table for correct wire placement. There are 2 pairs of these wire guides which differ only by the horizontal shifting of the rows of dowel pins intended for either the X or U(V) frame. The pins are machined to 25 μm accuracy. Two rail of jigs, placed on both sides of the wire frame, are attached to the table. To align the aluminum jigs, a few test wires spanning the length of the wire frame is secured on a screw of both jigs stretched across the active window. Then, the jigs are shifted until the wire is situated on the correct pair of electrical contact pads which are 200 μm wide and located just along the edge of the active window, and then clamped down. The accuracy of inter-pin spacing of the dowel pins on the aluminum railing is better than of the etched contact pads of the wire frame. For this reason, the wires do not generally sit on the same part of the contact pads relative to the others. On average, however, all the wires are situated in the middle of the copper pads.

The process of stringing the wires is fairly simple and quick. The wire is pulled

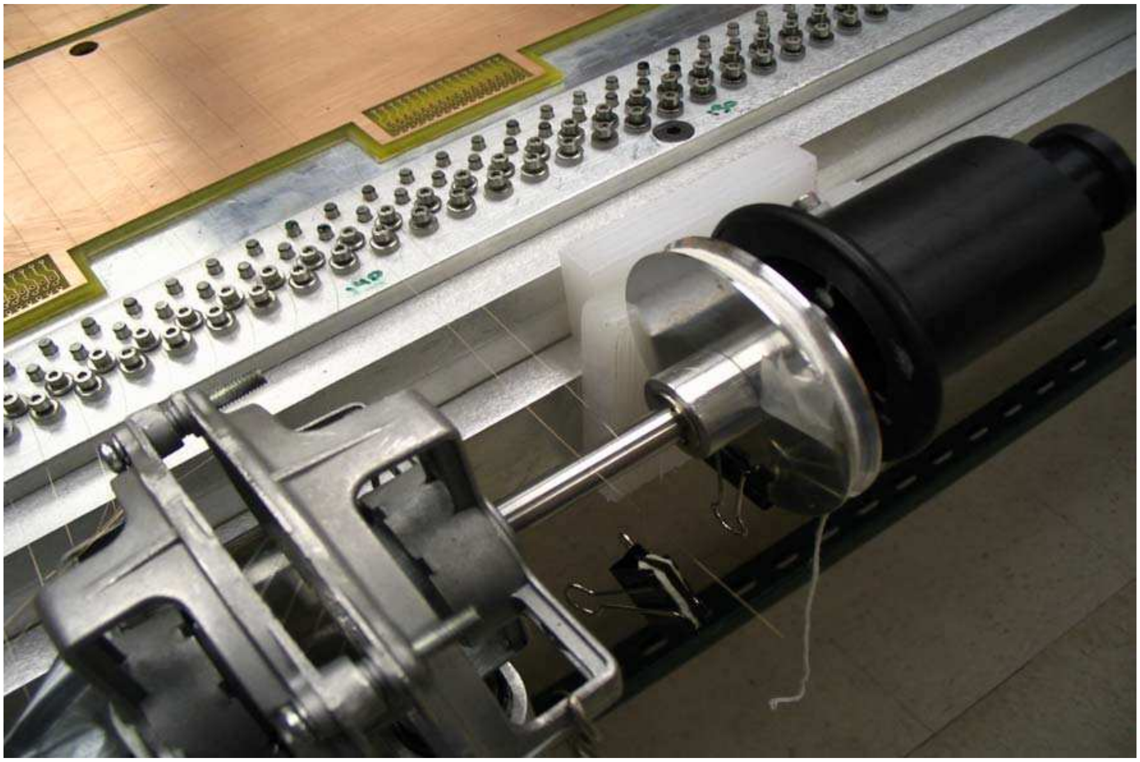

Figure 4.7: The free end of the wire is supported by a level arm where tension can be applied.

from the spool from one side of the wire frame to the other side. The wire, whose end is still attached to the spool, is then secured by the screws on the jig. To create tension, the free end of the wire on the other side needs enough slack to extend past the jig so that it can be attached to the proper weight. The weight is then attached to the wire which is hung over a smooth rod creating the necessary tension on the wires (Fig. 4.7). After properly adjusting for the wire position by making sure the wire is not touching the wire frame except at the contact pads, the free end is secured by the screw.

The wire spool is attached horizontally to a reel with an arm that can move along the length of the chamber. As each wire is strung, the reel arm can be translated a few centimeters to line up with the next wire pin in the jig. Therefore, the point where the wire is unwound from the spool is colinear with the corresponding pins on each aluminum jig. This also prevents the unwinding wire from interfering with the spool itself which destroys the integrity of the wire.

4.3.2 Tension Measurement

Tension measurements of sense and field wires are important because they have to be mechanically stable in the presence of high electric fields. Tensions less than desired will cause the wires to sag. This destroys the uniformity of the field throughout the chamber betweeen the wires and between the wire and the cathode plane. For these horizontal drift chambers, the field between the wires are more significant. Since the field coming from the wires are $\approx \frac{1}{r}$ dependent, a slight increase in inter-wire spacing will disturb the field lines and can the skew the drift time measurements. Care must also be taken not to make the wires too taut. Under conditions of high electric fields, a slight attraction of the wires to either each other or the cathode plane will cause the wire to snap.

Applying the proper tension to the signal and field wires involved a simple technique of applying weight to the free end of the wire while stringing. In the early development of chamber construction, a motor with a variable transformer was used to apply tension. The motor was adjustable to the necessary tension needed and could be connected to the wire spool directly to apply the desired tension. The technique was changed to merely attaching weights due to better consistency in applied tensions and a much quicker rate of stringing. The acceptable tensions are 70 grams for the field wires and 40 grams for the signal wires. Higher tensions for the field wires were avoided in order to prevent undue stress on the wire frame ($\approx$ 14 kg on each side). The signal wires deform at around 100 grams.

After the stringing of each frame the wire's tension and position are checked before the wires are permanently attached (with epoxy) to the frame. The wire

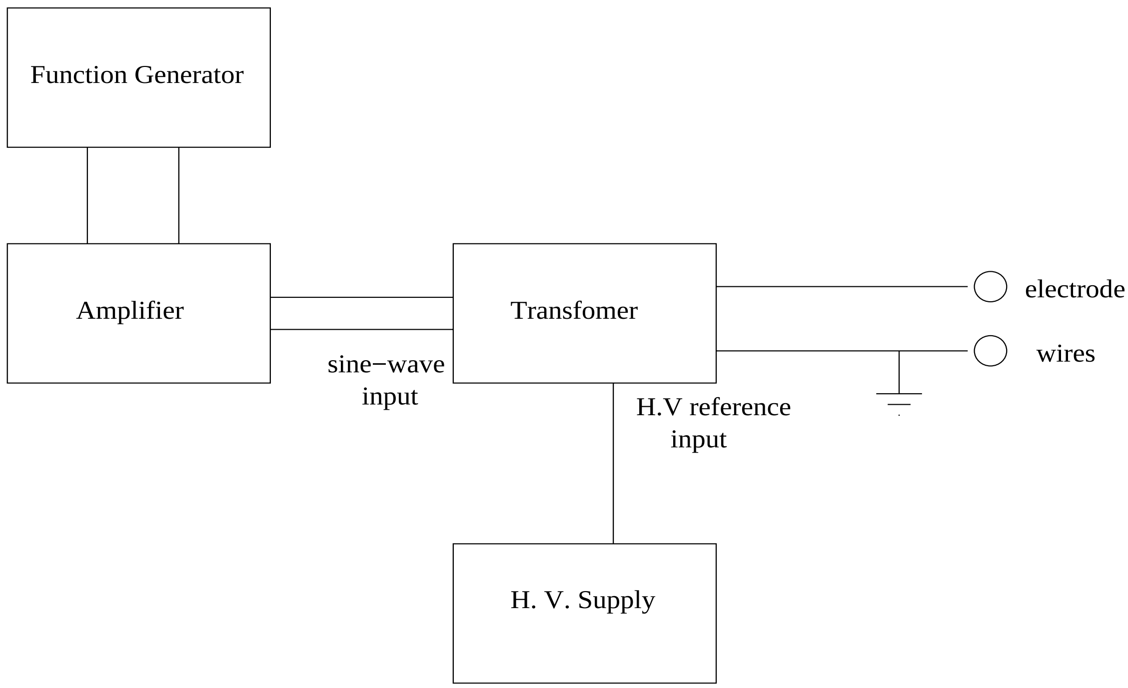

Figure 4.8: Layout for measuring tension. The electrode is a long piece of aluminum placed a few centimeters about the wires and spans the frame.

tensions are measured by grounding all the wires and the frame and placing an electrode, under high voltage, across the wire frame (Fig. 4.8). The wires are only held down by the screws of the jig. It is crucial that any part of the wire does not come in contact with the wire frame or the support table. This prevents friction from disrupting the desired tension. However, since the wires have to be attached to the frame, the wires are allowed to touch the frame just along the active window. Therefore, the length of the wire is barely longer than the width of the active window. Wire tensions can then be measured knowing the length of the wire.

By applying an AC Voltage across an electrode the wires and the electrode form a variable capacitor. The frequency of the function generator is tuned until the electrostatic force between the wires and the electrode induces an oscillation. We observe these oscillations visually for each wire and note the resonance frequency, ν. The tension can then be calculated using Eq. 4.3

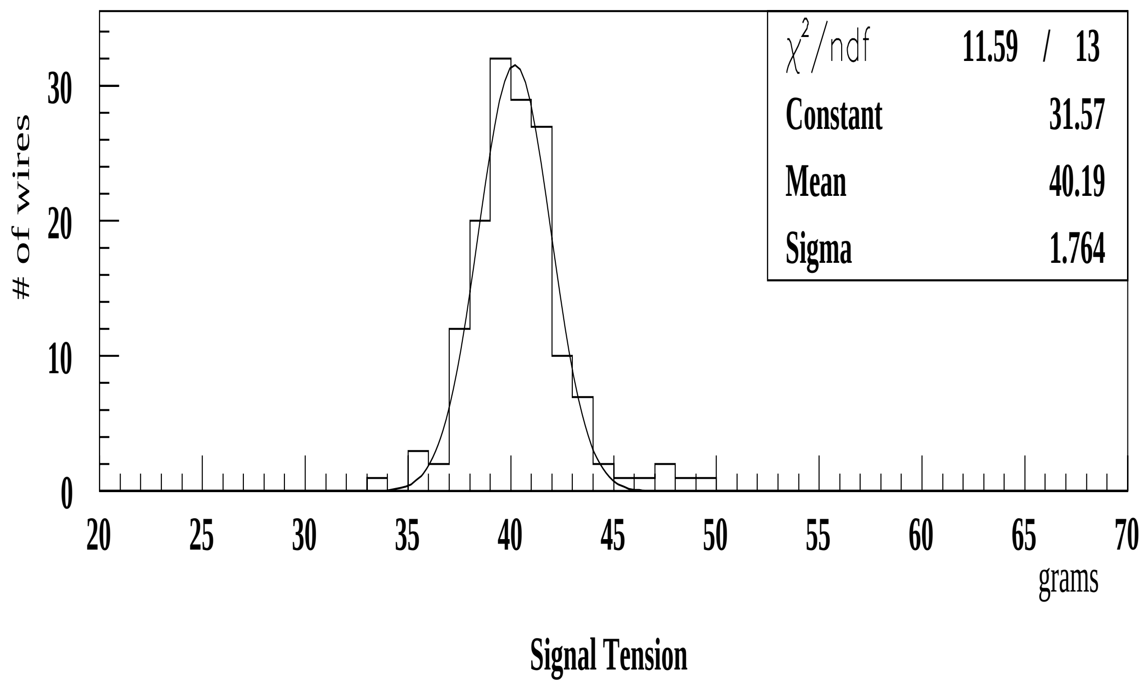

Figure 4.9: Tension measurements for signal wires

$$T = (2L\nu)^2\mu \tag{4.3}$$

L is the length of the wire in the active region and μ is the linear mass density of the wire. μ_{field} is $5.35\times10^{-5}kg \cdot m^{-1}$ and μ_{signal} is $6.03\times10^{-6}kg \cdot m^{-1}$. After measuring the tensions for the wire frame, any wires with tensions outside the $\pm10\%$ of the nominal value were restrung. Figure 4.9 shows the tension histogram for signal wires on a U plane. Tension measurements are summarized in Table 4.1

4.3.3 Position Measurement

After the tension of the wires have been measured the next procedure is to secure them onto the plane using an epoxy adhesive, Araldite® 2011. A mixture of resin/hardener (4 parts:5 parts) was stirred thoroughly and placed into a syringe to contol the amount of epoxy to each wire. The long, sharp tip of the syringe

Tensions of wire frames				
Frame(Chamber)	T_{field}	σ_{field}	T_{signal}	σ_{signal}
U'(1)	77.34	12.32	36.49	4.35
X (1)	62.29	5.68	38.86	2.32
X'(1)	61.74	4.53	36.99	2.35
U(2)	62.32	6.43	39.10	1.65
X(2)	70.82	4.51	40.62	1.62
V(2)	71.18	5.64	41.34	1.62
U(3)	59.29	4.29	41.33	3.00
U'(3)	53.96	7.40	38.09	2.27
X(3)	68.72	6.47	42.03	2.83
X'(3)	71.64	3.75	40.61	1.62
V(3)	64.87	5.03	40.19	1.76
V'(3)	71.18	5.64	41.34	1.63

Table 4.1: Tension measurements (in grams) for wire frames

also prevents interfering with the wire while placing the glue drops. This method involved placing the tip right to the side of the wire and letting glue seep out while lifting the tip over to the other side of the wire. The glue then settles into a small blob covering the wire without disturbing its position. A drop ($\approx$5 mm) of the mixture was placed on the wire between the edge of the active window and the copper contact pads (Fig. 4.5). The drying process took about a day for the mixture to completely harden.

Before the epoxy hardens, the wire's position is measured so that they can be corrected if necessary. Otherwise, the epoxy needs to be removed (dissolving with a hot soldering tip proves to be the quickest and cleanest solution) and the wire restrung. Measuring the positions of the wires over a frame about 2 meters long to a precision better than 50 μm proved to be challenging. A non-invasive method using an optical device made position measurements possible without touching the wire. A CCD camera attached to a stepper motor was used for this measurement. The motor was controlled by a computer through a serial interface. The camera is

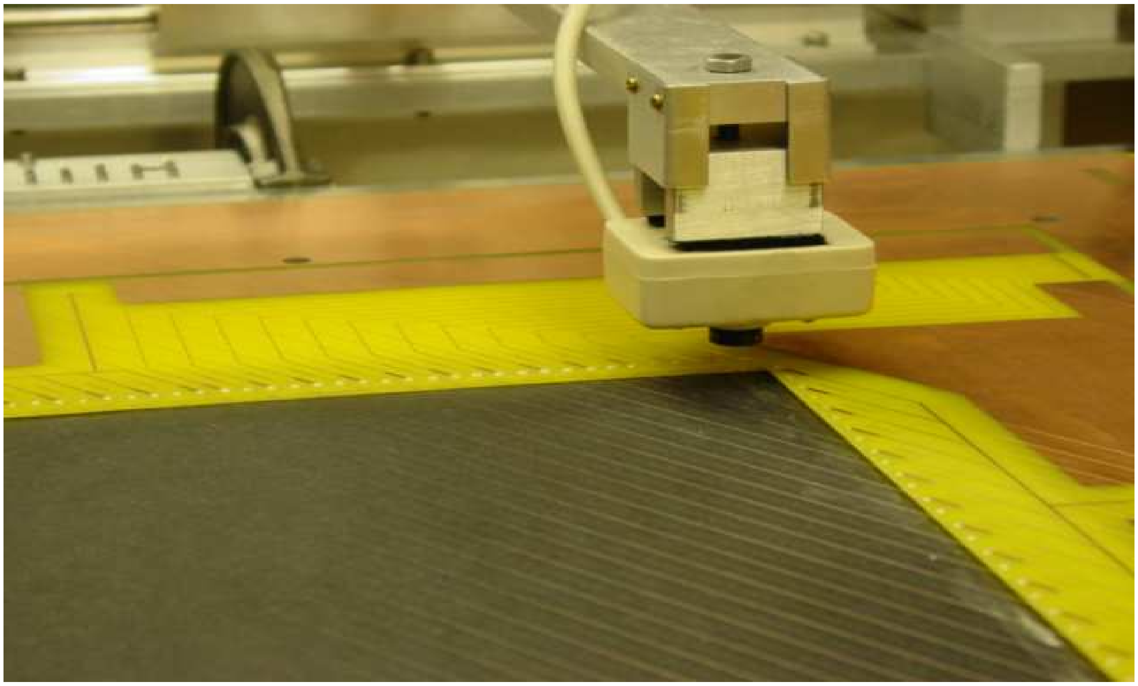

Figure 4.10: Camera overlooking the frame allowing to measure the distance between the wires.

attached to a long arm and overlooks each wire (Fig. 4.10) displaying a magnified image on a monitor. A reference point can be used on the screen in reference to the wire to determine its position. The stepper motor then translates the camera along the frame onto the next wire. The stepper motor has a precision of 0.5 μm. The resolution of the camera, however, cannot discern this and the overall accuracy of this measuring device was determined to be $\simeq$35 μm. We allowed a tolerance of $\pm$75 μm although the deviations are usually smaller by a factor of 2. Position measurements for an X plane are shown in Figure 4.11.

Wires were soldered onto the copper contact pads to ensure solid electrical connection (also shown in Fig. 4.5). In order to avoid any slight displacement of wires, soldering was done only after the epoxy completely hardened. After all the wires were fixed to the frame by epoxy and solder the remaining wires were unscrewed from the jig and carefully removed. To prevent leaving a small tail exposed at the

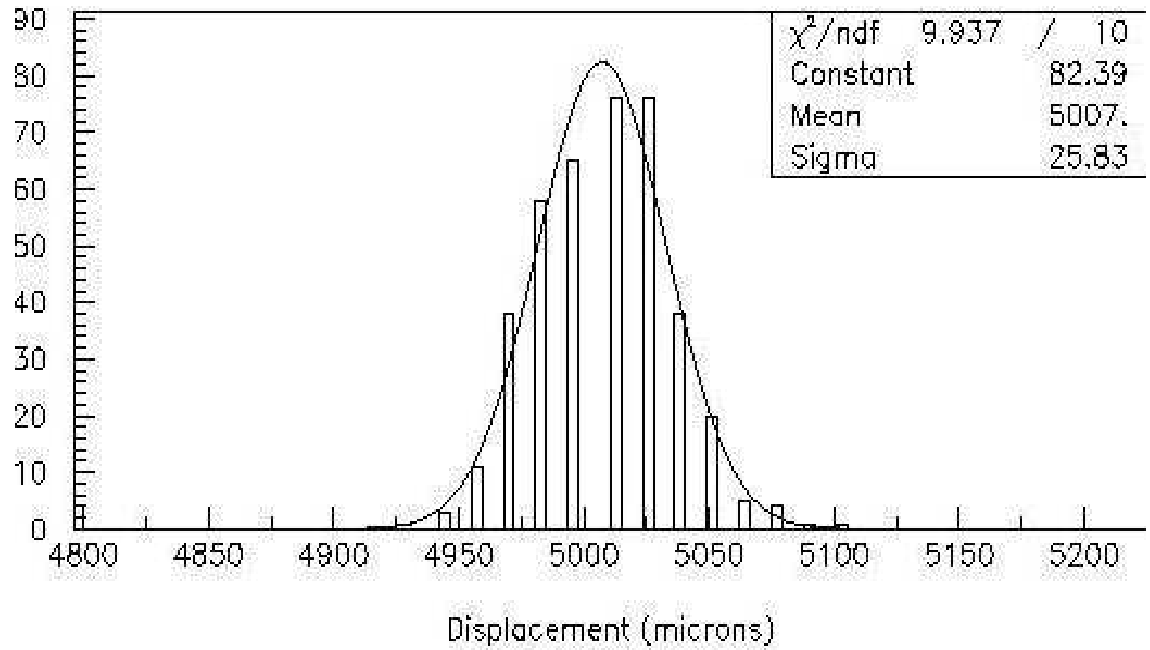

Figure 4.11: Position measurements for X frame

lead or adhesive drop, the wires were carefully twisted off. This causes a problem in that the tail acts like an antenna and produces undesired fields which are picked up by the signal wire. During testing of chamber 1 noisy channels were found which constantly registered hits at a greater rate than other wires. We inspected the chamber by opening it up and noticed that the exposed wire tails were the cause of the noise. This was remedied by coating them with epoxy.

4.4 Cathode and Gas planes

The cathode planes provide high voltage to the chamber to help shape the electric field. The film used to provide the high voltage is copper (1200 Angstroms) coated DuPont mylar (0.5 mil) from Sheldahl. The outer most frames in the chambers are gas windows which are grounded conducting planes. The gas film is made of a thin layer of 1 mil aluminized kapton, also from Sheldahl.