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ES&F Division Technical Note # 167

From Conducting Paint to Ion Chamber and Beam Profile Monitor

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Dysart Ravenhall

June 7, 2010

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Introduction

This paper describes the process of using conducting paint in the fabrication of Ion Chambers and Beam Profile Monitors. After a brief introduction, a number of examples of chamber designs are described, along with the role that conducting paint plays in their design.

Historically, when constructing wire/drift chambers, conducting paint has been used on the bias plane. The added resistance of the painted traces helps to reduce the intensity of sparks. We have used GRAPHIT 33 sold by the KontaktChemiecompany. In searching for a replacement for carbon spray, we found three alternatives: liquid silver paint applied with a miniature paint brush, liquid paint applied with a pen and two kinds of aerosol spray paint. These are nickel spray paint, Aerosol 3801 and Silver Coating 3850 manufactured by Holland Shielding System BV. The spray paint is initially insulating, but becomes conductive after it dries. It also adheres very well to plastic. The cost of each can is fairly high, about 190 Euros each. A similar product, Super Shield Conductive Coating 841 from action-electronics.com, is available at a much lower price, \$30. Both products worked well with our application. Figure 1 shows the Holland shielding product.



Figure 1: Aerosol spray paint and Silver Coating 3850.

A: Mouse Chamber

NASA was interested in exposing a large number of mice in the large beam, 60 cm x 60 cm. This mode of operation required us to create a large beam with an additional new magnet for the new tune. We also needed to build a large beam profile chamber to monitor the uniformity of the beam distribution. The exposure time is expected to be several hours. In order to monitor the beam uniformity, we decided to build an ion chamber using a Lucite box that is normally used as a sample holder for mice. This allows us to easily mix the chamber with the mouse. The paint gave us that ability. Figure 2 shows the Mouse Chamber of dimensions 3.7 cm x 3.7 cm by 8.5 cm long.



Figure 2: Mouse Holder Chamber

The ion chamber is functionally separated into two regions: a gas volume in the front of the chamber and a charge collection volume in the back of the chamber. In order to separate the detector region, a paper curtain was placed between the two regions. The paper curtain and inside of the front chamber are painted with silver conducting paint. Figure 3 shows the prototype. The high voltage is connected with the red wire to the inside chamber.



Figure 3: Disassembled painted Mouse Chamber

The collector rod is shielded in the outside region to avoid “seeing” charge generated in the back chamber. The rod is soldered onto the LEMO connector. The connector ground is then connected to the wall of the outside chamber. This way, the charge created in the outside of the designated ion chamber can bleed through the ground connector. The connector ground also acts as a guard ring. The outside paper curtain is also painted with silver paint. This allows the charge generated outside the ion chamber to bleed off towards the connector ground.

We then place the collector rod through the opening of the paper curtain and stretch the paper across the chamber opening. We then tape the chamber together. For grounding, we spray the outside with Aerosol Spray paint. Figure 4 shows the finished chamber. The Banana jack is for the bias voltage and LEMO is for the signal.

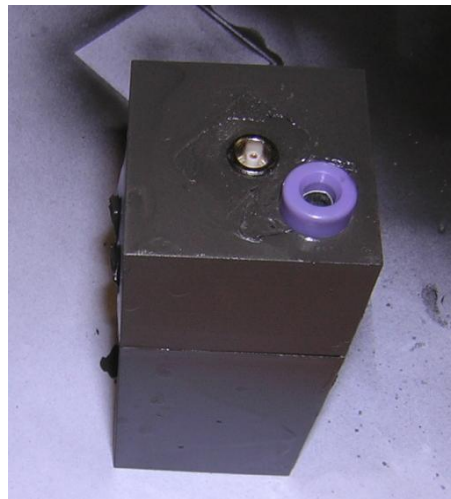


Figure 4: Finished Mouse Chamber

We then placed the chamber in the beam to check the performance. Figure 5 shows the result of a plateau curve of one of the Mouse Chambers as a function of dose rate and ion species.

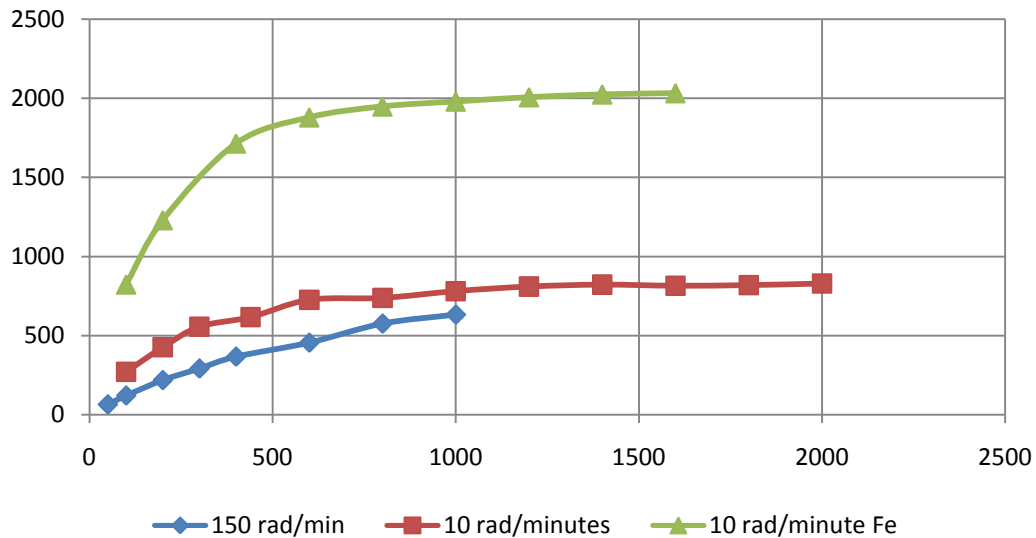


Figure 5: Charge collection efficiency of the Mouse Chamber as a function of dose rate and ion species for Carbon (blue and brown) and Iron (green) ions. The vertical axis is proportional to the charge collected by the signal rod. The horizontal axis is the voltage on the Mouse Chamber

It clearly shows the chamber is well behaved at 10 Rad/minute, although at 150 Rad/minute it never reaches a plateau. We set the bias voltage at 1500 V and we only intend to use them near 1 Rad/minute.

We also built one with larger mouse chamber, 5.7 cm x 5.7 cm x 10.6 cm. The Plateau curve did not level off, as shown in Fig. 6. The large diameter provides too much room for recombination. We decide against using this model as an ion chamber.

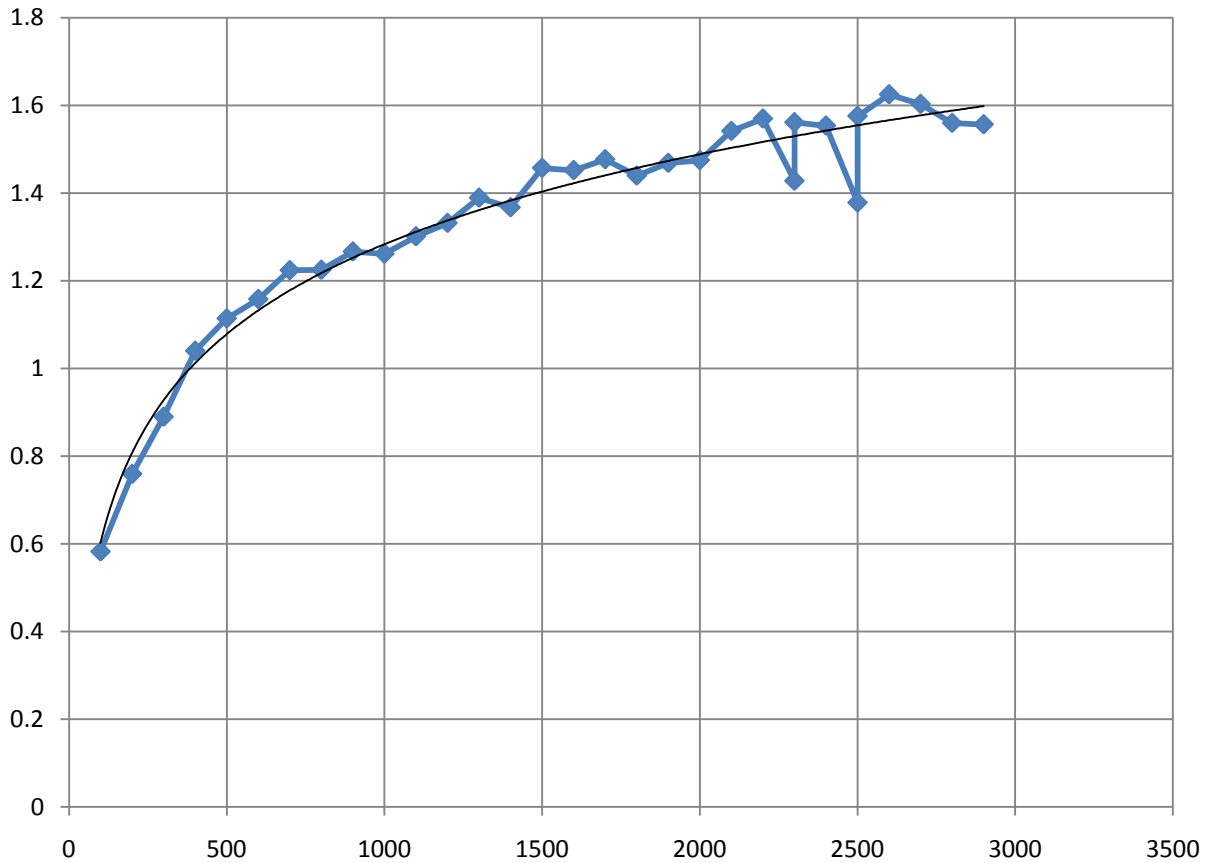


Figure 6: Plateau curve for a Large Mouse Chamber. Vertical axis is proportional to the charge collection efficiency. Horizontal axis is the voltage on the Large Mouse Chamber. Data are shown in blue, with a logarithmic fit in black.

We had made 5 small mouse chambers that were tested in the beam. The initial observations are good. The responses are equal to within $\pm 3\%$ of each other. The plan for use is to distribute the Mouse Chambers throughout a large array of samples to monitor the beam uniformity, as shown in Figure 7. A more detailed study is needed to further clarify this. But for the purpose of monitoring the beam distribution and stability, it is more than adequate.

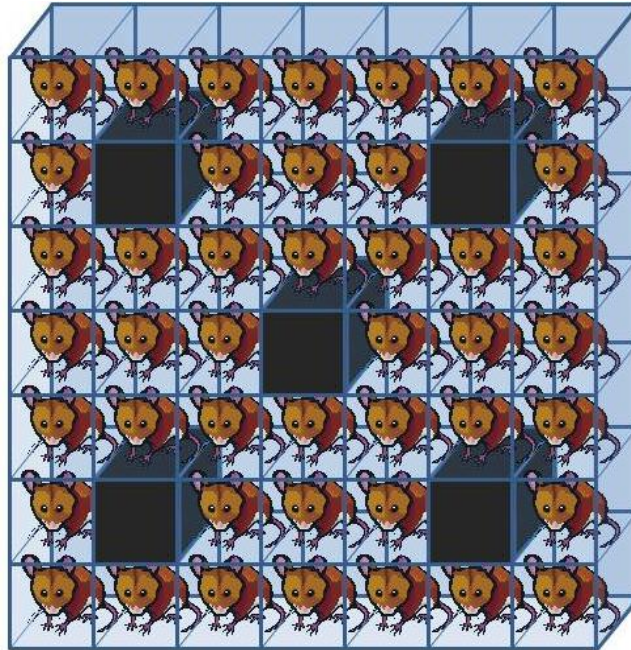


Figure 7: Typical arrangement of Mouse Chambers throughout an array of samples for use during a large beam exposure.

B: Air Pixel Chamber

Our original vision of the large beam project was to build a large pixel chamber with gain. It would have two signal planes, one of 16x16 pixels and the other 8x8 pixels with a wire plane in between (see [NSRL-TN-09-001](#)). This configuration enabled the chamber to have gain. For this implementation, we did not have enough electronics for a 16x16 array; instead we started with an 8x8 array with 8 cm square pixels. Due to the departure of the NSRL Mechanical Engineer, the mechanical design was not completed. At the initial commissioning of the large beam, it was realized we could utilize the partially finished collecting plane in air to monitor the beam. We painted over the 16x16 plane as the bias plane and used the 8x8 plane as detectors for which we had the integrating electronics. Without the wire plane we will not have gain, but it is adequate for normal running. Figure 8 shows the 16x16 plane painted over by spray paint turning it into a bias plane. The other plane was wired up to the 8x8 pixel plane.

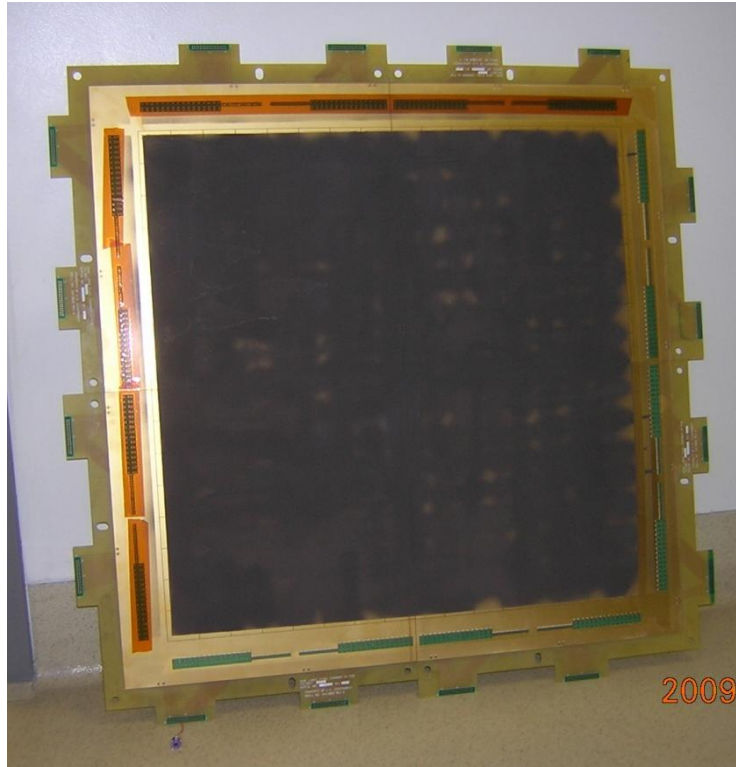


Figure 8: Painted 16x16 bias plane

The two planes were then mounted on the rails with a 2 inch air gap between them. This configuration performed very well for the beam commissioning. Figure 9 shows the setup. The front plane is the 8x8 pixel plane with foam backing which is intended to keep the plane flat. As it turned out, the foam was not adequate. But the chamber is still performing very well.

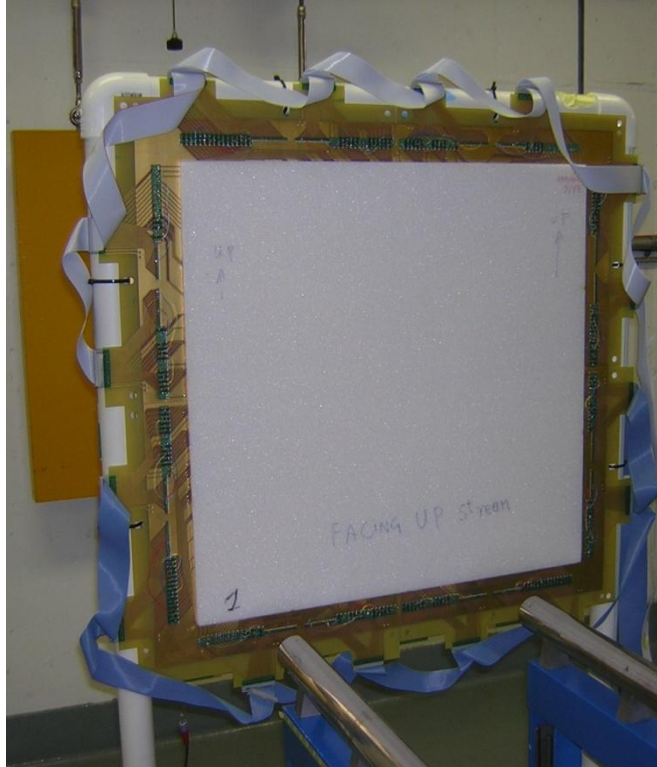


Figure 9: Photograph of the Air Pixel Chamber mounted at the end of the NSRL rails.

With the success of the spray paint, we realized that we could make an air chamber with thin foils. We started with an original PC board design and stretched a sheet of 5 mil thick Kapton on it. Due to the limitation of PC board manufacturing capability, we had to make the chamber out of 4 boards. We designed the board so that we could wire up the chamber in either of the two configurations: an 8x8 or 16x16 array. We needed to combine the 4 pieces of PC board into a single chamber. We then glued the frame onto a stretched 5 mil thick Kapton foil. We then made the pixel pattern with 1/8" masking tape before spraying on the conducting paint. The back side of the PC board was used to connect the pixels to a special PC board for electrical connection. The connection was done with conducting paint using the pen.¹ The following pictures show the device. There is a small hole drilled in the middle of each pixel. A trace drawn with the conducting paint connected the pixel through the hole to the trace on the back plane. It is then connected to the PC board trace. In this way, the connections to the outside are more robust.



Figure 10: The 8x8 pixel plane. Each pixel is 8 cm square.

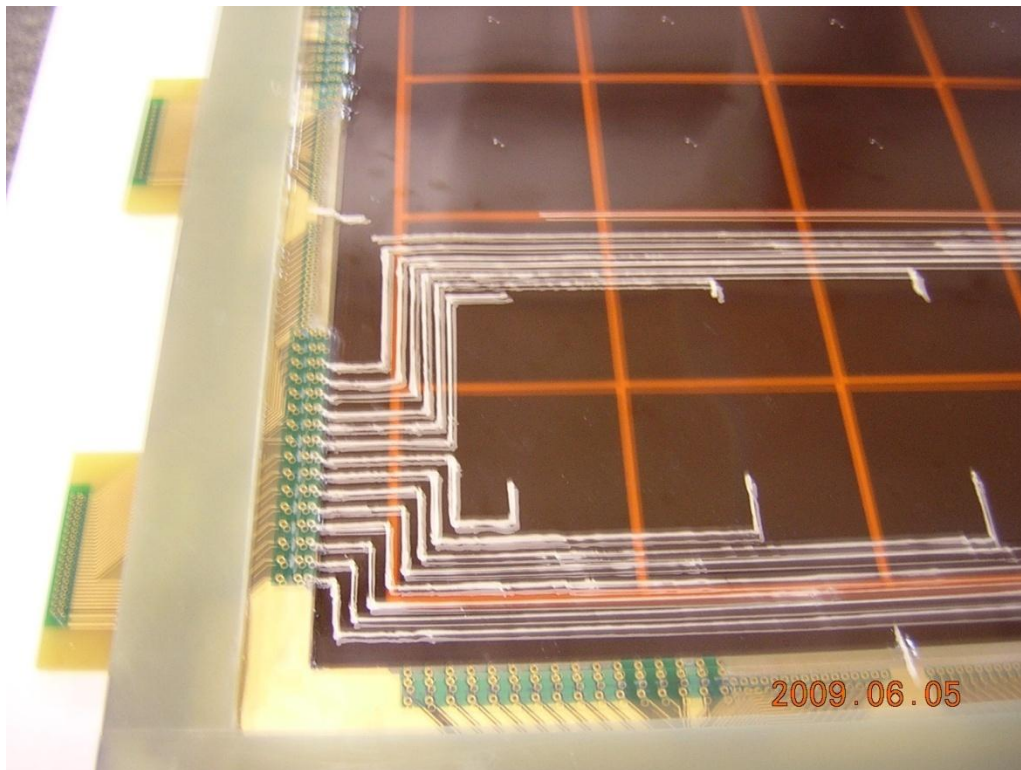


Figure 11: The pixels are connected to the PC board to display the electronics.

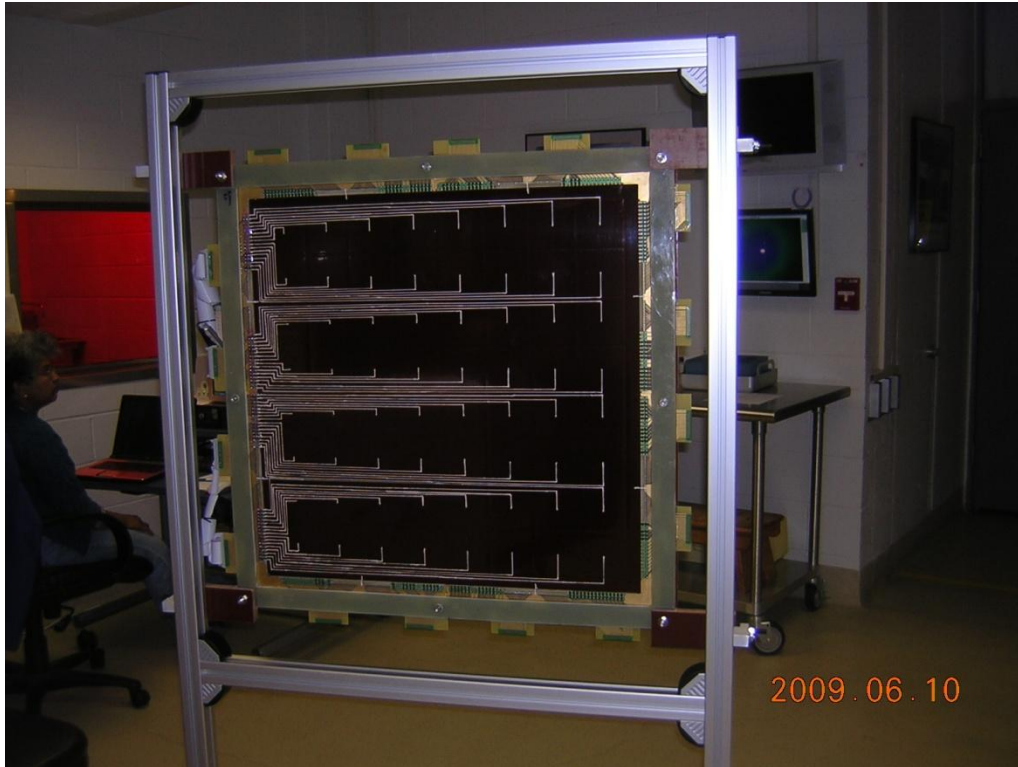


Figure 12: The final assembly of the large air gap pixel chamber.

The electronics used in this display are standard C-AD 8-channel integrators. It was then connected our control system software for display which uses software from J. G. Chart by Quest Software. Figure 13 is the beam profile display produced for the large pixel chamber. This program allows us to display the pixel values in the form of 3-D surface plots or bars. It also allows us to rotate the display to show the pattern from different angles.

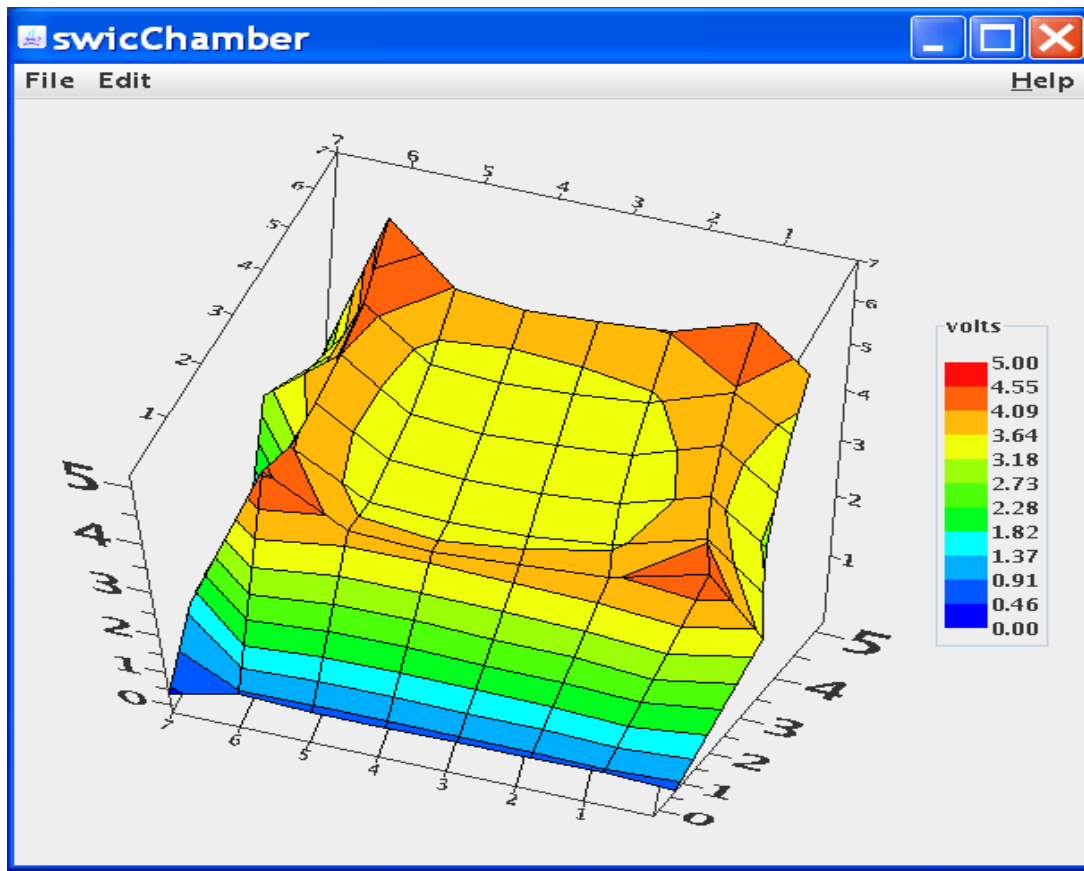


Figure 13: Pixel Chamber Display, 8x8 with 8 cm square pixels.

We have already designed a new version of 16x16 pixel PC board. It provides a guide for back trace connection. Since we have not yet run a large beam program, we will wait and see whether we need to make a final 16x16 chamber. In the new mode of design, we will not need to design a new recycling integrator. The recycling integrator can accept a negative polarity chamber only. The Pixel chamber with gain needs a positively biased wire plane. The air chamber can be of either polarity. We could use the existing 16x16 recycling integrator, except that we need to make 16 new cables with different connector ends.

C: New 302 chambers

In preparing for the upcoming run, we need to minimize the beam path. We decided to remove the upstream instrumentation. In doing so, it became obvious we should build a new 302 chamber with foil. This time, we built into the design an option of selecting two different wire spacings, 6 mm or 12 mm, by using an intermediate connecting block. We can easily change the effective wire spacing

with a simple change of connector. The normal chamber is made of 32 wires with 12 mm spacing. We made the chamber with 6 outside wires on either side to be 12 mm. The center 16 wires were replaced by 32 wires with 6 mm spacing. The total 48 "wires" were sprayed on the 3 mil Kapton film using conducting spray paint. We spray painted the foil after masking out the wire distribution. The wires were then connected with traces of conducting paint to the PC board with 60 pin connectors. We had an intermediate board made so we could connect either the center 32 x 6 mm wires to the electronics or double up the center 32 to 16 and connect the outer 16 wires to make 32 x 12 mm wires.

Again, this new method allows us to make a chamber that is very specific for our use without a lot of engineering.

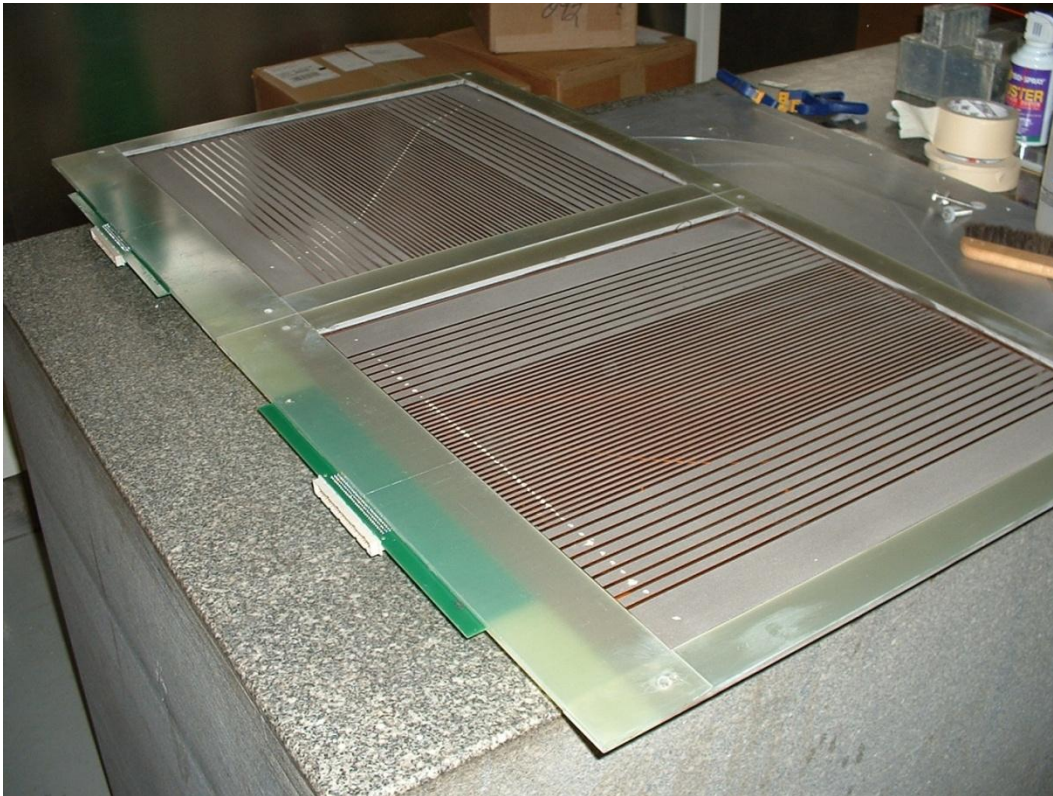


Figure 14: The "wire" plane for the new 302 ion chamber. One plane is the horizontal wires, and the other plane is the vertical. The connector is designed to be on top.



Figure 15: Back side of the 302 ion chamber, showing connections to the readout PC board.

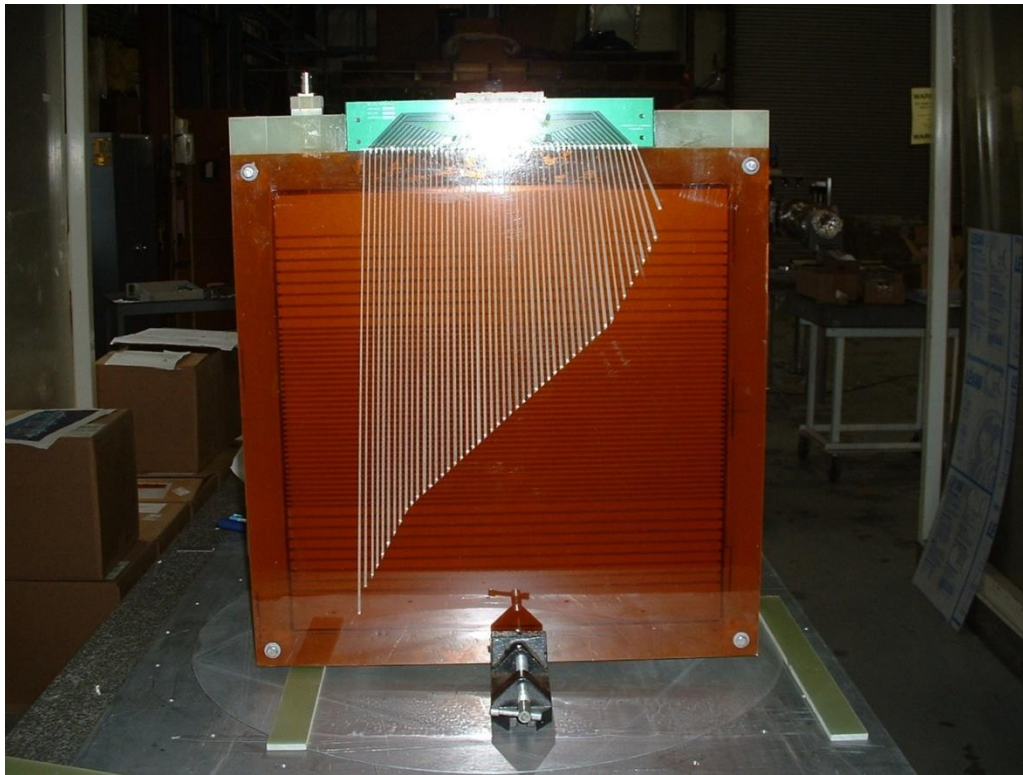


Figure 16: The finished new 302 ion chamber.

D: Spread out Bragg peak chamber- SOBPC

In studying the energy loss of ions due to ionization as a function of range using dosimetry film, we have been puzzled with the observed LET increase as the Bragg peak is approached. The Bragg peak observed in film is not as big as the Bragg peak measured with ion chambers. After a long study we realized the film response depends on the LET, i.e., the film response is not linear with dose. Although we could calibrate the film with ion chambers, it would be a very tedious and time consuming process. We are studying a way to deliver a spread out Bragg peak as is done in cancer treatment. Now since we have learned how to make chambers quickly, we decided to make a 16-layer ion chamber with polyethylene. We chose to use 1 mm thick stock for the degrader and $\frac{1}{2}$ inch material for the frame. The conducting plane was sprayed on with conducting spray paint after taping out the clear area. This way we could control the conducting area. Figure 17 shows the can and film.

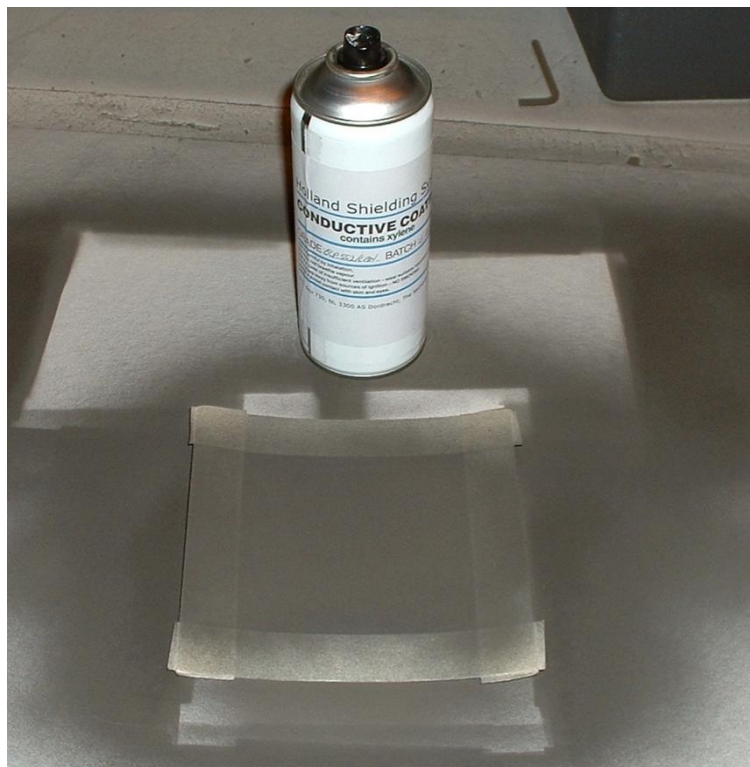


Figure 17: Spray paint on the 1mm thick Polyethylene sheets.

The film is then glued onto a frame, made out of $\frac{1}{2}$ inch polyethylene material. The conducting plane is then connected to the Banana pin using conducting paint

traces from the pen applicator. To reduce the probability of leakage from high voltage to signal, we decided to separate the two. The signal chamber uses both side for charge collection. There are two banana pins in the signal chamber. For the bias chamber, both sides are connected to the same High voltage. The two connectors were used to daisy chain the HV so that we do not need to have more than one connection. Figure 18 shows the signal chamber. Figure 19 shows the finished chamber. The red pins show the daisy chained high voltage. The white pins are the signal connectors. They were then connected to a multipin connector for recycling integrator input. We tested the chamber with a proton beam at a dose rate of 35 R/minute with a beam size of 5 inches by 5 inches. The chamber plateau curve looks very good. We conclude that 1500 volts will be safe for most of the beams we can deliver. Figure 20 shows the plateau curve for the first 8 chambers we made.



Figure 18: Signal chamber. Both sides are used for charge collection.

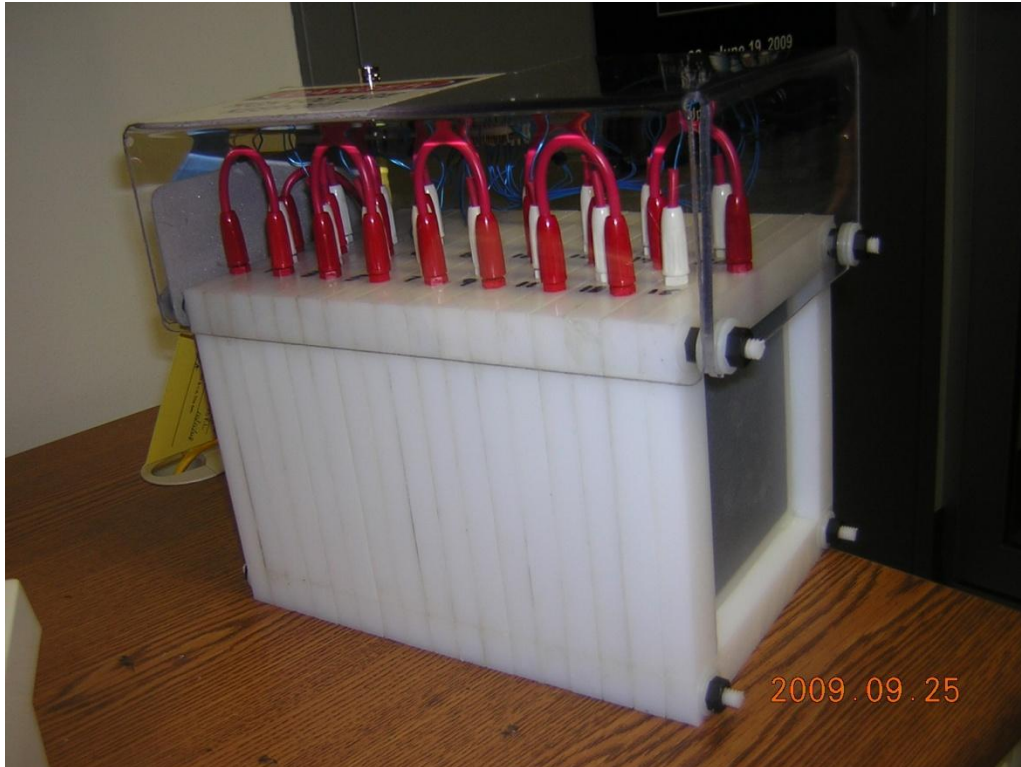


Figure 19: Assembly of all 16 chambers showing HV connection in red and signal connections in white.

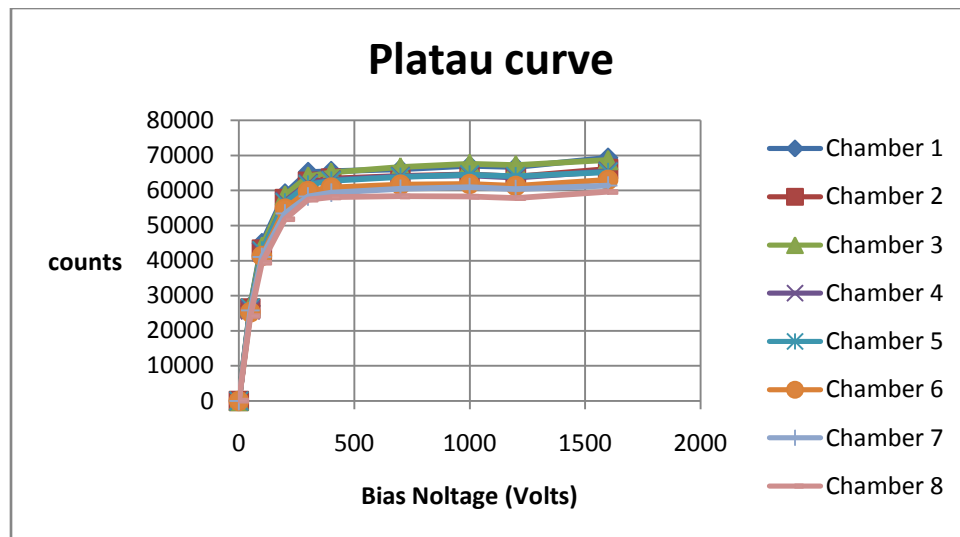


Figure 20: Plateau curve for the first 8 chambers in the 16 chamber stack.

We then test the chambers with the designed dose distribution. We developed the dose distribution by trying various doses at different beam energies. We then fit the dose/energy relation with a calculation. The curve shows the combination of two different degraders. First is done with beam fully stopped in the SOBP

chamber. After the run, we then removed from the degrader an amount of polyethylene equivalent in thickness to the SOBP chamber. This way, we could show the Spread out Bragg peak as if we had 32 chambers. Fig. 5 shows the distribution.

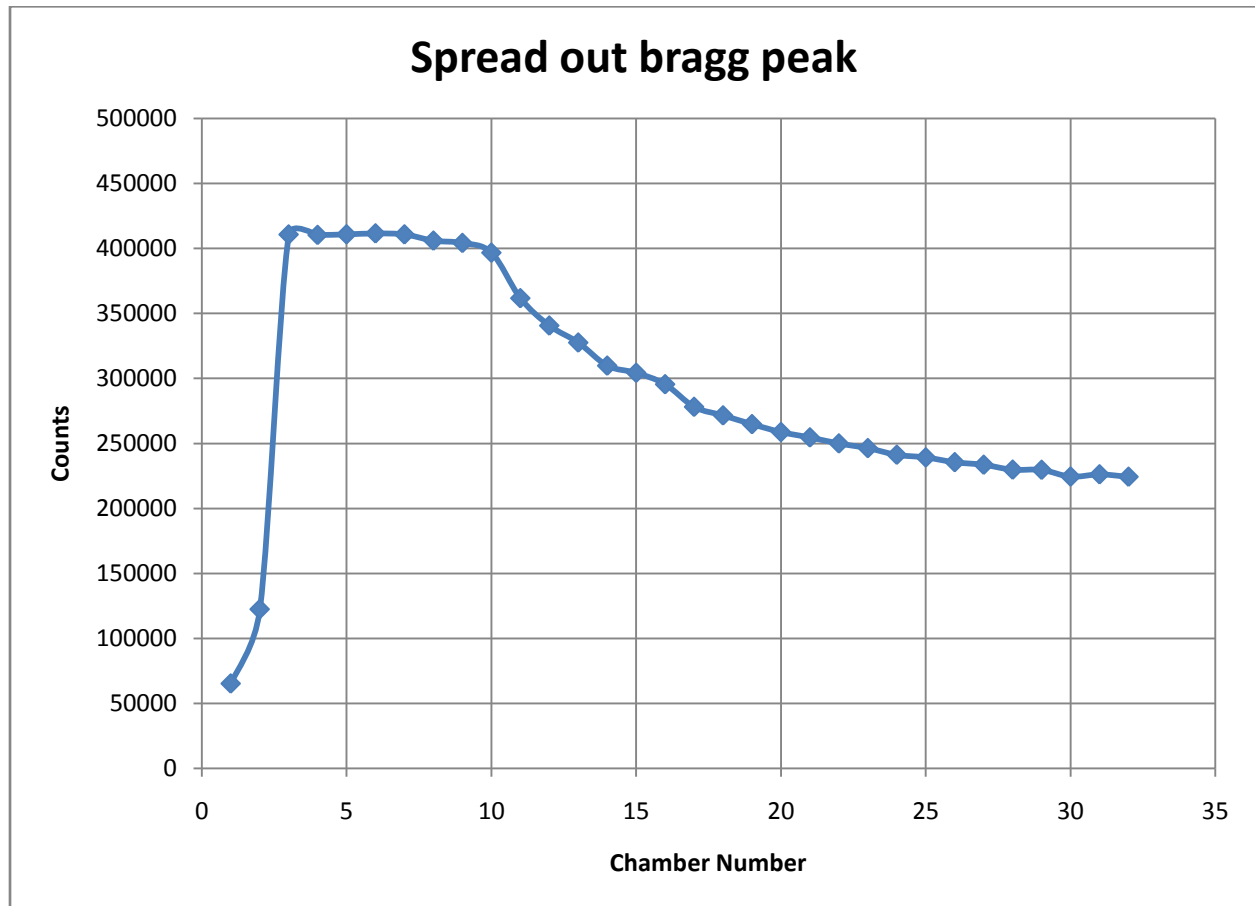


Figure 21: Spread out Bragg peak from using the 16 chamber stack twice, the equivalent to a 32 chamber stack.

In developing this chamber, we learned how to make a thin foil chamber; instead of 1 mm Polyethylene we use the 3 mil Kapton. We are using these chambers to measure Bragg peaks for gold in the upstream area. The existing degrader is too bulky to move, and does not have fine enough steps to measure the Bragg peak of the gold beam.

ⁱ. Thanks to Daniel Lehn who suggest the conducting pen instead of the silver brush paint.