MCP Upgrade: Transmission Line and Pore Importance

Tyler Natoli

For the PSEC Timing Project

Advisor: Henry Frisch

June 3, 2009

Abstract

In order to take advantage of all of the benefits of Multi-Channel Plate Photo-Multiplier Tubes (MCPs) a fast and efficient readout scheme must be implemented. One scheme that appears very promising is that of a transmission line coupled to a digital sampling readout. Transmission line readout allows for 2D position reconstruction, as well as an extremely fast response time, allowing for an exceptional timing resolution. I will be discussing the development of a method to connect the transmission line readout to the anode of the MCP, as well as testing the resultant MCP-transmission line readout system. This testing occurred at Argonnes laser lab, which featured a tunable fast rise time laser as well as a data acquisition system with a low noise level. A study to determine the importance of the pore size of the MCP was also carried out at Argonnes laser lab. In this study two MCPs which differed only in pore size (25μm and 10μm) were tested and their timing resolutions were compared. The objective of the following discussion is to quantify the effectiveness of the transmission line readout, learn more about the nature of the MCP and its signals, and look for ways in which to improve upon the present readout technique.

1 Introduction

Micro-Channel Plate Photo-Multipilier Tubes (MCPs) have been used for signal amplification since the 1960s and are now an intricate part of many experimental setups. The basic workings of an MCP is the same as any normal Photo-Multiplier Tube (PMT), light is transferred into electrons via a photocathode, then the electrons go through a dynode structure for amplification, and are finally readout onto an anode. The main advantage gained by using an MCP instead of a normal PMT is gained from the use of very small ($\sim 10\mu$m) pores instead of a dynode structure for electron amplification [1]. By using very small pores the difference in path length between electrons created from the same initial signal is minimized, thus creating a faster rise time on the amplified output signal. Depending on the method of readout of the MCP this fast rise time can be turned into an extremely good ($<$10psec) timing resolution [2]. The following discussion focuses on the benefit of a transmission line readout coupled either to a Constant Fraction Discriminator (CFD) or a fast sampling readout. Since the micro-channel plates themselves are the most unique and integral parts of the MCP signal amplification, special attention must be paid to their parameters. It has been shown that the amount of ion feedback created in an MCP can be greatly reduced by using a Chevron style channel orientation [3]. All of the MCPs used in the following discussion are Chevron type MCPs. One of the current parameters being researched with MCPs is the width of their pores. It has been said that the width of the pores play a major part in the rise time, and thus the timing resolution, of the MCP output signals [4]. The following discussion will conclude with an argument backed by the comparison of two identical MCPs save for a different pore size, as to the validity that notion of pore size is a major aspect of the timing resolution of MCPs.

2 Transmission Line Readout

The Transmission line card used was developed by Fukun Tang [5]. It features a 32 x 32 pad grid in which pads along one direction are connected through a 50 Ohm transmission line and read out at either end of the line, as shown in Figure 2.

Each of the 1024 pads (32x32) need to be individually coupled to exactly one of the 1024 pads (32x32) on the anode of the MCP. This presented a problem, since there is no physical way to solder each of these pads to each other due to space constraints.

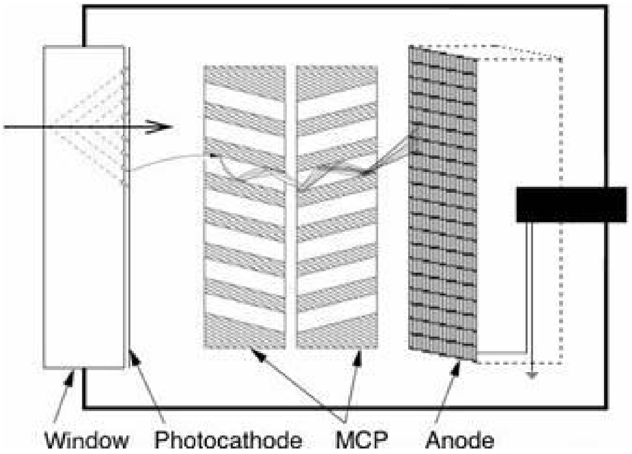


Figure 1: A schematic of a typical MCP assembly making use of the Chevron style.

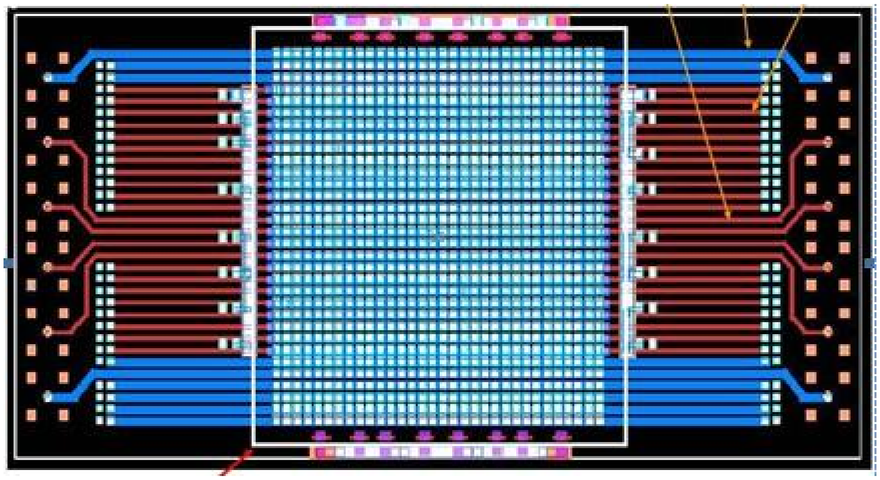


Figure 2: A view of the Transmission line board showing the transmission line connections within the board and their respective read points on the sides of the board.

To solve this problem we enlisted the help of a conducting epoxy. This epoxy showed the ability to be spread well, cure at a temperature that was suitable to subject an MCP to, and showed reasonable uniformity in resistivity as shown in figure 3a.

This conducting epoxy was applied to an MCP anode over a stencil which restricted the location of the epoxy to only circular regions centered on each of the 1024 pads. To aid with the attachment the Transmission line cards were solder bumped on

Figure 3: (left) A histogram of the resistivity across the conducting epoxy when attached to a Transmission line board and dummy MCP anode. (right) An image of the actual transmission line board and dummy MCP anode just before being epoxied together.

each of their 1024 pads and the solder bumps were then roughened up to increase the surface area and effectiveness of the epoxy adhesion. A picture of an MCP attached to a transmission line card via the conducting epoxy discussed here is shown in figure 4.

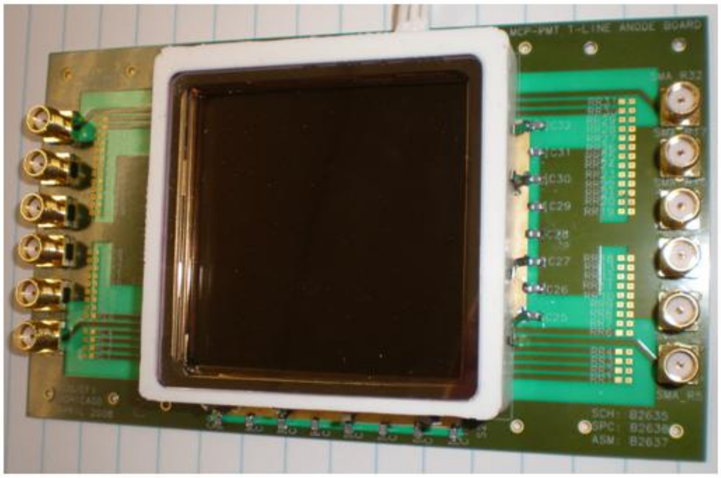


Figure 4: Here an MCP attached the Transmission line board is shown. On this particular version of the transmission line board only 6 transmission lines are read out, these are shown with the SMA connectors in the image.

As can be seen from figure 4, not all of the transmission lines are read out using the current version of the transmission line board. The version of the transmission line board that was attached to the MCP tested here had the capability of reading out six of the 32 transmission lines via SMA connectors, as seen in figure 4.

The Transmission line readout scheme is used because it allows one to gain position information in two dimensions. In the direction perpendicular to the transmission line, the position of a signal is simply taken by which transmission line the signal is located on (or in the more advanced case, fitting a Gaussian to the signal seen in multiple adjacent transmission lines). Figure 5 shows that the position in the direction perpendicular to the transmission line can be easily found in this manner, as only a localized pulse is created as the laser is swept over the active transmission line.

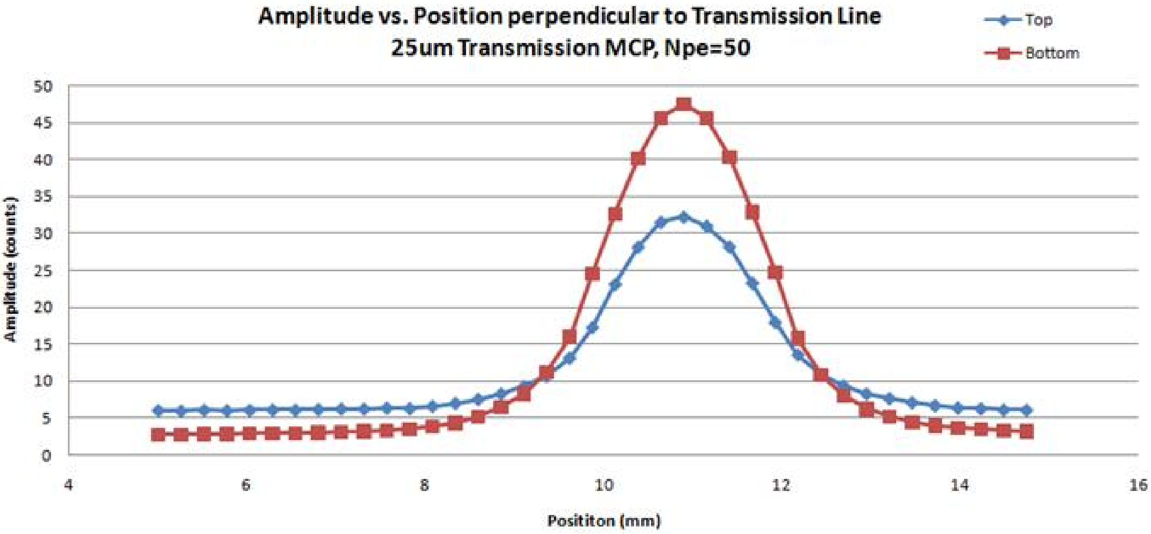


Figure 5: A laser with an approximate width of 1mm is scanned across a 25μm MCP perpendicular to the transmission lines while only one transmission line is being readout.

The position resolution along the direction of a transmission line is found by comparing the time of arrival from the pulses seen at either end of the transmission line. This means that the timing resolution that we get from comparing the two ends of the same transmission line dictates what our position resolution will be.

As seen from figure 6, the timing resolution of the Transmission line board is extremely good, ~3psec. This translates to a position resolution along the direction of the transmission line of <100μm.

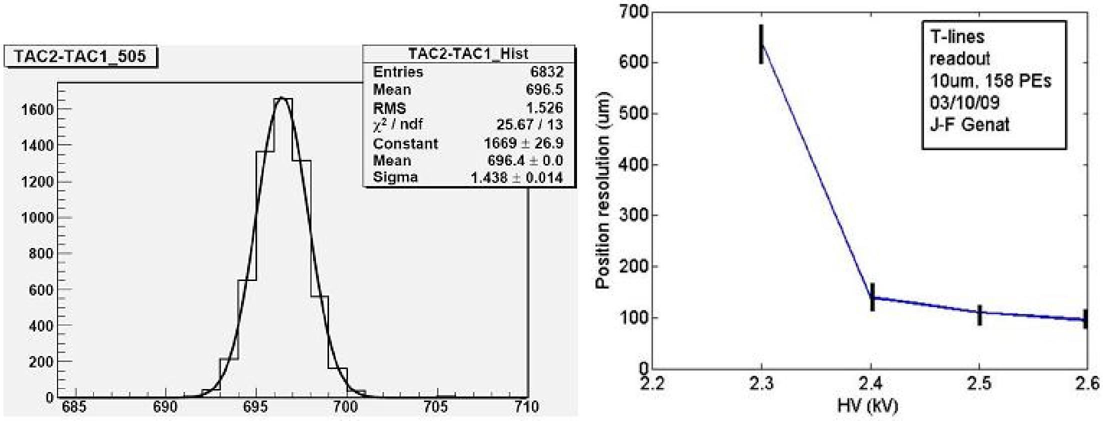


Figure 6: (left)A sample histogram of the timing difference between the two ends of a transmission line fit with a Gaussian and showing a timing resolution of ∼4.5psec (3.1psec/bin shown). (right) Jean-Francois Genats timing resolution data translated into a position resolution curve for different applied voltages to the 10μm MCP at 158 photoelectrons.

3 Argonne Laser Test Stand

Now that the MCPs have been attached to the Transmission line board, and have been shown to exhibit good signal and behavior, we can begin to test other features of the MCP. The Argonne laser lab was the location in which the next set of test were run on the MCP-Transmission line combination. A simplified version of the Argonne laser lab can be seen in figure 7.

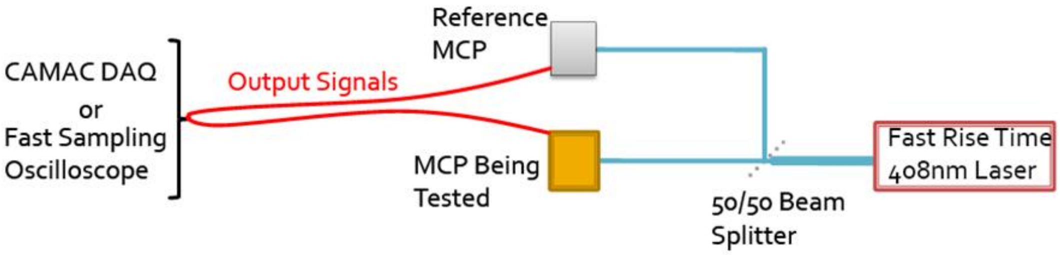


Figure 7: A simplified cartoon of the setup at the Argonne laser lab. For more detailed specs of the Argonne laser lab, consult reference 6.

At the Argonne laser lab there are two different methods in which to read out the MCP signals created by the laser. The first method is a CAMAC DAQ, before the signals enter this DAQ system they are first put through a Constant Fraction Discriminator (CFD) and an amplifier with a fast rise time. This DAQ system records relative timing information between the two MCPs as well as pulse amplitude information for both MCPs. The second DAQ method is a Fast Sampling Oscilloscope capable of sampling a single channel at 40GSamples/sec (or two channels at 20GSamples/sec). When the Oscilloscope is used as the DAQ, all information about the pulses is recorded, since the actual pulses themselves are recorded, no information is lost and the timing information and pulse amplitude information can be extracted from the data at any time. Both of these DAQ systems were used in order to corroborate results and perform cross checks between the two systems.

4 10 vs. 25 μm MCPs

One of the big questions with MCPs is; how dependent is the timing resolution pore size? With the Argonne laser lab setup just described we have the capability to compare two MCPs that differ only in pore size. The MCPs compared were Burle MCPs, one had 10μm pores, while the other had 25μm pores, other than this difference, the MCPs were as close to identical as possible. Both MCPs were attached to the Transmission line readout through the conducting epoxy method described above. The MCPs were then tested in the Argonne laser lab under a variety of differing conditions. Some of these conditions included altering the; voltage applied to the MCP, photoelectron level, transmission line being read out, and spatial location activated along a particular transmission line.

As can be seen in Figure 8, the Transmission line readout when coupled to the fast oscilloscope gives full detailed pulses. When viewing the full pulses we can see whether the MCPs are operating in saturation mode (nearing or in saturation mode at 2.5kV for 158PEs), as well as check for the rise times expected (<0.5nsec). Examining the full pulses also allow us to see that the Transmission line boards do not significantly alter the shape of our signal and therefore preserve the fast MCP rise time.

One thing that we must be sure of when comparing the 10μm and 25μm MCPs is that we are comparing them at equal gain levels. Since the electric field present within the pores is related to the pore size and the voltage applied, we must apply a higher voltage to the 10μm pores than to the 25μm pores to get the same signal amplitude, or amplification, out. In other words, simply comparing the MCPs at equal applied voltage levels is not enough, we must make sure that they are at equal amplification levels in order to properly compare them.

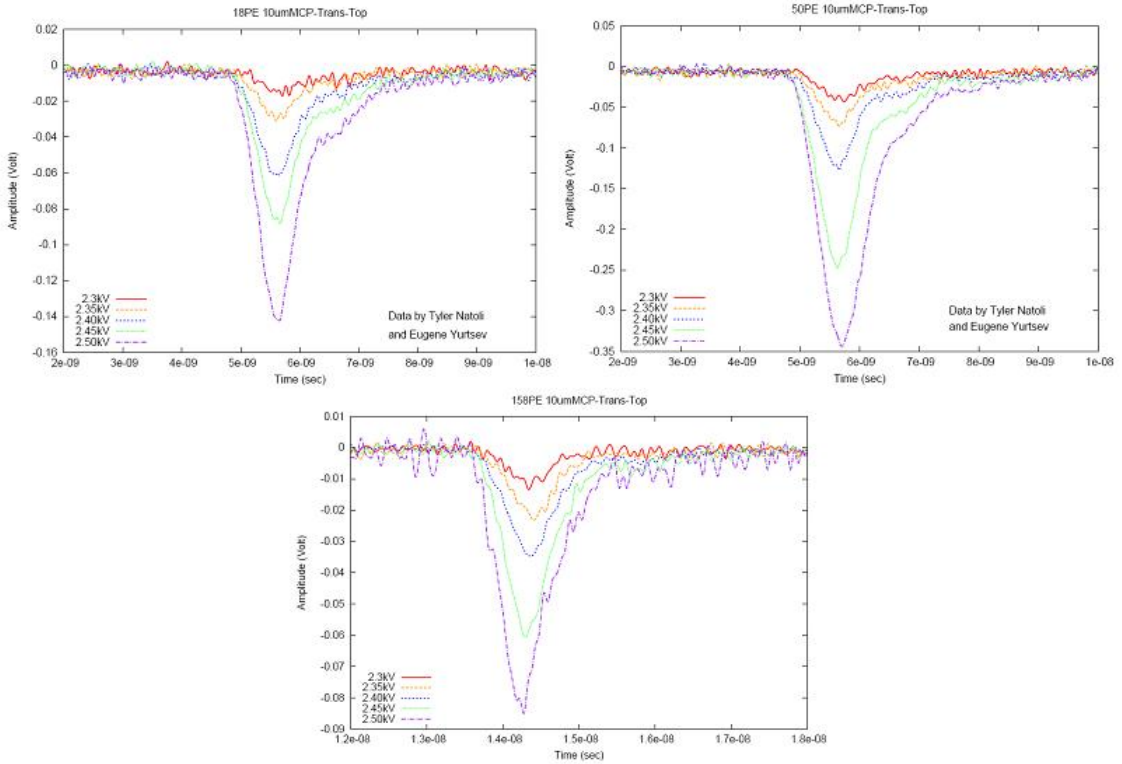


Figure 8: Typical pulse shapes are shown across applied voltage and photoelectron level for the same 10m MCP coupled to a transmission line board and readout with a fast sampling scope.

Figure 9 shows how the amplitudes of both MCPs scale with applied voltage. From this plot it can be clearly seen that we are currently operating the MCPs in very different gain regimes, and only the very highest voltages currently applied to the 10μm MCP match the linear gain regime seen in the majority of the 25μm MCP curve. Unfortunately the voltage applied to the 10μm MCP cannot be raised higher to due fear of breaking the MCP. (The documentation from the manufacturer states not to exceed an applied voltage of 2.5kV over the MCP).

Figure 10 shows how the timing resolution scales with the amplitude (or gain) of the signals coming from both the 10μm and 25μm MCP. Again, the only relevant comparison points occur when the MCPs are operating at the same gain level. The two MCPs exhibit approximately the same amplitudes (or gain levels) in the linear gain region for two points, one for the 50 photoelectron case, and another for the 18 photoelectron case. The settings for these common gain levels can be seen in Figure 11.

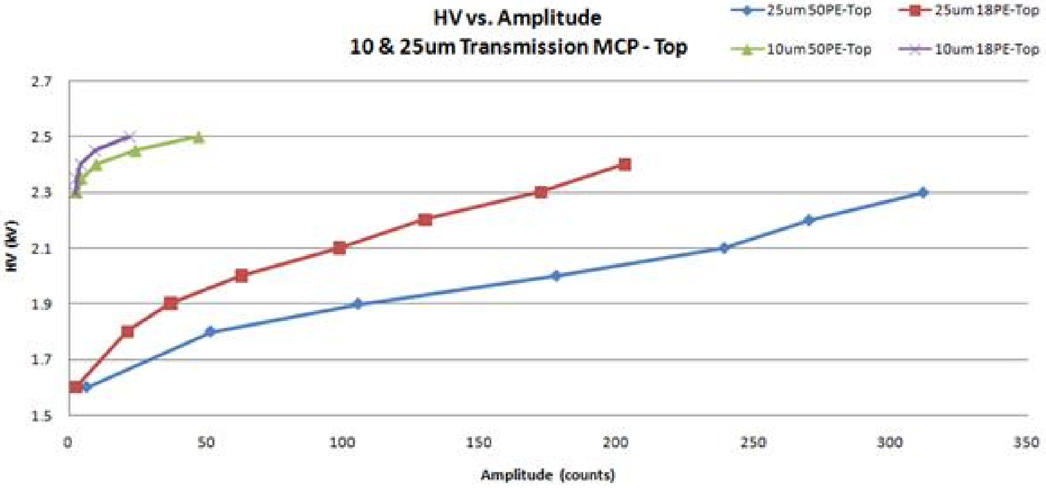


Figure 9: The applied voltage is plotted against the amplitude in counts (1 count = 0.250pC) for both MCPs at 18 and 25 photoelectrons.

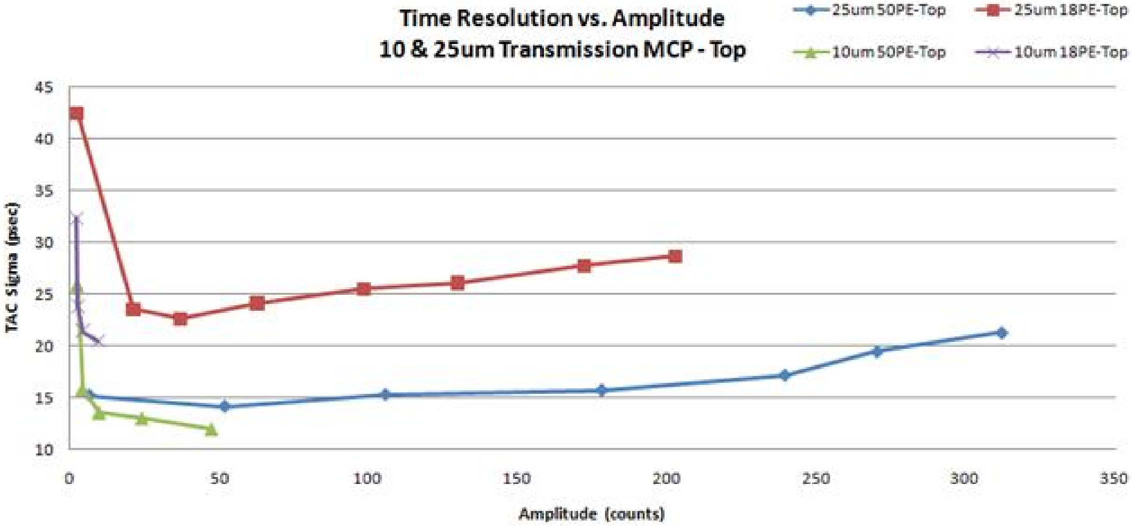
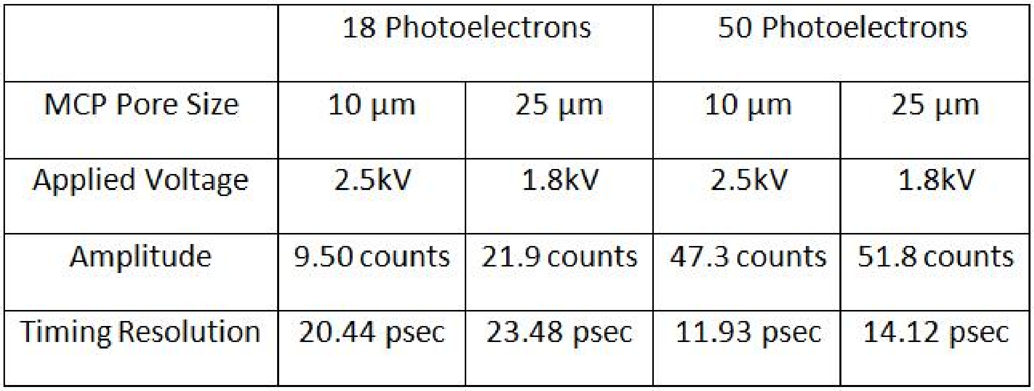


Figure 10: The timing resolution is plotted against the amplitude in counts (1 count = 0.250pC) for both MCPs at 18 photoelectrons and 50 photoelectrons while varying the applied voltage. This is the same data represented in Figure 9.

Since at these points the MCPs are operating at relatively the same gain levels, their timing resolutions may be compared. The common gain level points for the 50 photoelectron case is more appropriate to use when comparing the two MCPs since the amplitudes match up to within ten percent. From this point it can be seen that the



	18 Photoelectrons		50 Photoelectrons	
MCP Pore Size	10 µm	25 µm	10 µm	25 µm
Applied Voltage	2.5kV	1.8kV	2.5kV	1.8kV
Amplitude	9.50 counts	21.9 counts	47.3 counts	51.8 counts
Timing Resolution	20.44 psec	23.48 psec	11.93 psec	14.12 psec

Figure 11: A comparison of points that show similar gain levels. This data is that same as that shown in Figures 9 and 10.

timing resolution at a similar gain level improves by approximately 15 percent (from 14.12 psec to 11.93 psec) when going from a pore size of 25μm to 10μm. This shows that a better timing resolution is achieved when using a smaller pore, however, it does not match up with the nave theory predicting that the timing resolution scales by the same factor as the pore width. With such a small improvement in timing achieved from such a large change in pore width it brings into question the cost/benefit factor both for the manufacturing of and continued research for smaller pore widths.

5 Conclusion

It was shown that when a transmission line readout is used for the readout of an MCP that a position resolution of under 100μm and a timing resolution of a $\sim$10 psec can be easily attained. This position resolution is consistent with the prediction of the inherent time spread of the transmission line board itself. This shows that the transmission line readout works on the order of inches, and should be able to be elongated to work for large area MCP detectors. It was shown that the pore size of the MCP does not play a crucial part in determining the timing resolution of the MCP. By varying the pore size from 25μm to 10μm a slight ($\sim$15% difference in timing resolution at the same gain level was seen, but this difference was less than what the current manufacture literature cites.

Even without a transmission line readout MCPs are important and useful tools for experimenters. However, when you combine the intrinsic small size and time spread of an MCP with an impedance matched position sensitive readout, like that of the transmission line readout, the MCP becomes a much more powerful tool capable of attaining timing resolutions on the picosecond order and position resolutions under 100 micrometers.

Acknowledgments

I would I would like to thank both Henry Frisch and Jean-Francois Genat for their help throughout the project, specifically Jean-Francois for greatly assisting me in both the taking of data, and comprehension of its implications. A portion of this work was also done under the guidance and aid of Ed May and Eugene Yurtsev at Argonne National Laboratory and their efforts are also greatly appreciated.

References

[1] J. Milnes and J. Howorth,Picosecond Time Response Characteristics of Microchannel Plate PMT Detectors. SPIE 5580 (2004).

[2] J.F. Genat, G. Varner, F. Tang, and H. Frisch; Signal Processing for Pico-second Resolution Time Measurements; Nov. 2008.

[3] J. Wiza, Microchannel Plate Detectors Nuclear Instruments and Methods. 162 (1979) 587.

[4] J. Milnes and J. Howorth, Advances in Time Response Characteristics of Microchannel Plate PMT Detectors.

[5] F. Tang et al., Transmission-Line Readout with Good Time and Space Resolutions for a Planicon MCP-PMT. Poster presented at the Topical Workshop on Electronics for Particle Physics (TWEPP), Parallel Session B6 - Friday 19 September 2007. Prague, Czech Republic.

[6] http://psec.uchicago.edu/testing.php