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NEUTRAL CURRENT DETECTOR DEVELOPMENT PROGRESS

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INTRODUCTION

We have continued our work toward the development of a practical detection system for neutrons that can be included in the SNO heavy water tank. We are still considering two approaches: First, we are investigating gas filled detectors that rely on ionization produced by the charged particles resulting from neutron capture on ^{3}He or ^{10}B. Second, we are looking into the detection of scintillation light that is produced by the passage of the charged particles through ^{3}He and other gas mixtures.

POSITION SENSITIVE GAS-FILLED PROPORTIONAL COUNTERS

A method for determining the position, along the detector axis, that charged particle passes through a gas filled proportional counter has been demonstrated. This position sensing method is simialar to that reported by Uritani *et al.* [1] The event position in the detector is obtained by dividing the part of charge imparted upon the counter anode which moves toward the preamp side of the counter, by the total charge imparted upon the anode. Theoretically, this charge ratio should be linear with the event position in the detector, ranging from 0 to 1.

The counter used for the position tests was made from 1.5" diam. stainless steel tubing that was 36" long. Three holes were drilled in the counter wall and covered with thin aluminized mylar to provide for generation of events at different fractional distances along the counter. A source of ^{241}Am was placed at one of the three covered holes to generate events at 0.667, 0.500, and 0.250 of the full length of the counter for holes 1, 2, and 3, respectively.

The counter system schematic is displayed in Diagram 1, which shows the counter and the electronics system used to interpret the counter signals. P-10 gas flowed through the counter at 585 torr and was used as delivered from the gas cylinder without further purification. The counting data were collected using a CAMAC system connected to a PC-AT class microcomputer. For each event, the pulse heights detected in the fast and slow channel were recorded. The ratio of the fast to the slow channel pulse heights was

[1] **Novel Position Sensing Method Using Fast and Slow Components in An Output Signal From A Proportional Counter**, A. Uritani, C. Mori, T. Watanabe, and A. Miyahara, Dept. of Nuclear Engineering, Faculty of Engineering, Nagoya University, Nagoya 464, Japan, Presented at The Seventh Symposium on Radiation Measurements and Applications, Univ. of Michigan, Ann Arbor, MI, May 21-24, 1990.

then calculated to give the position of the event. The data system was triggered by a timing filter amplifier and discriminator in parallel with the fast and slow channels.

Before collecting data, the positions were normalized by adjusting the fast pulse gain so that hole #1 showed its theoretical value. 2000 events were then collected for each hole, and both the peak position and full width at half maximum value (FWHM) of the three distributions were recorded. Each parameter was systematically varied and set to its optimum value then process was repeated with a new parameter.

Seven parameters in the counter system were examined to determine their effect upon the position measurement:

1. Anode voltage of the proportional counter.

2. Capacitance at the end of counter (which collects the part of charge moving away from the preamp).

3. Pulse amplifier shaping time for the fast channel (the amount of time the electronics collect the charge moving toward the preamp).

4. Pulse amplifier shaping time for the slow channel (the amount of time the electronics collect the total charge).

5. Timing filter amplifier gain (adjusts the sensitivity of the gate generator).

6. Gas flow rate (the rate at which gas is pumped through the counter).

7. Anode wire resistance.

DATA AND RESULTS

Counter Voltage. The voltage to the counter was varied from 900V to 1300V, and this data is shown in Table 1. As the voltage increased, the position separation increased and the resolution slightly decreased, until the voltage reached 1300V and the preamp became saturated.

Table 1. Counter Voltage Test

capacitor=.010 uF; fast time=1 us; long time=16 us; gas flow=0.3 L/min

voltage (volts)	hole 1 (FWHM)	hole 2 (FWHM)	hole 3 (FWHM)
900	.667 (.022)	.591 (.024)	.444 (.023)
950	.671 (.020)	.588 (.019)	.429 (.020)
1000	.669 (.020)	.581 (.022)	.409 (.020)
1050	.667 (.017)	.562 (.020)	.375 (.021)
1100	.665 (.017)	.564 (.018)	.371 (.018)
1150	.666 (.020)	.558 (.020)	.371 (.022)
1200	.670 (.022)	.566 (.014)	.360 (.018)
1250	.666 (.019)	.566 (.015)	.361 (.017)
1300	no peaks were discernible		

Capacitance. Various capacitors were used, ranging from .001 μF to .068 μF, and the results obtained with the 1125 Ohm anode are displayed in Table 2. A capacitance of .010 μF optimized the position separation. The resolution was unaffected.

Table 2. Capacitance Test

voltage=1100V; fast time=1 us; long time=16 us; gas flow=0.3 L/min

capacitance (uF)	hole 1	hole 2 (FWHM)	hole 3
.0010	.672	.596 (.019)	.525
.0020	.671	.572 (.020)	.437
.0022	.669	.569 (.018)	.416
.0050	.667	.571 (.017)	.373
.0100	.667	.556 (.017)	.369
.0200	.672	.596 (.020)	.413
.0680	.667	.643 (.021)	.535

Fast Pulse Shaping Time. The shaping times from which to choose were very limited. In fact, two different electronics had to be used to get a wider range of values. It should be noted that the times on these two electronics were not congruent. For example, 0.5 μs on the Ortec 474 TFA seems to fall between 1 μs and 2 μs on the Tennelec 242. The data in Table 3 shows that as the shaping time decreased, the position separation increased, but the resolution increased as well.

Table 3. Fast Pulse Shaping Time Test

capacitor=.010 uF; voltage=1200V; long time= 16 us; gas flow=0.3 L/min

shaping time	hole 1 (FWHM)	hole 2 (FWHM)	hole 3 (FWHM)
Tennelec 242:			
4 usec	.668 (.007)	.598 (.006)	.473 (.010)
2 usec	.666 (.007)	.567 (.013)	.402 (.012)
1 usec	.668 (.018)	.560 (.013)	.361 (.016)
Ortec 474:			
500 nsec	.670 (.013)	.570 (.015)	.386 (.006)
200 nsec	.665 (.031)	.561 (.042)	.349 (.021)

Long Pulse Shaping Time. This parameter also had limited shaping times from which to choose, but one can see in Table 4 that as the shaping time grew from 4 μs to 24 μs, the position separation grew, while the resolution remained relatively unchanged.

Table 4. Long Pulse Shaping Time Test

capacitor=.010 uF; voltage=1200V; fast time=500 ns; gas flow=0.3 L/min

shaping time	hole 1 (FWHM)	hole 2 (FWHM)	hole 3 (FWHM)
24 usec	.665 (.015)	.545 (.014)	.365 (.012)
16 usec	.667 (.010)	.561 (.015)	.386 (.009)
8 usec	.665 (.014)	.598 (.014)	.462 (.015)
4 usec	.666 (.013)	.636 (.013)	.563 (.019)

Timing Filter Amplifier Gain. As Table 5 shows, the gain on the TFA seemed to affect only the position of hole 3. As a result, any linearity tests would have been useless because the #3 position could be set to make the three-point line as linear as desired.

Table 5. Timing Filter Amplifier Gain Test (normalized to hole 2)

capacitor=.010 uF; voltage=1200V; fast time=500 ns; long time=24 us

gain setting	hole 1 (FWHM)	hole 2 (FWHM)	hole 3 (FWHM)
gain as low as possible without losing hole 3 events	.603 (.010)	.497 (.015)	.320 (.012)
gain as high as possible without smearing hole 3 peak	.604 (.012)	.495 (.015)	.342 (.011)

Gas Flow Rate. Increasing the gas flow slightly increased the resolution of the counter, as shown in Table 6.

Table 6. Gas Flow Rate Test

capacitor=.010 uF; voltage=1200V; fast time=500 ns; long time=24 us

flow rate (L/min)	hole 1 (FWHM)	hole 2 (FWHM)	hole 3 (FWHM)
0.25	.670 (.016)	.551 (.010)	.362 (.012)
0.50	.669 (.015)	.552 (.015)	.361 (.013)
0.75	.668 (.017)	.547 (.017)	.358 (.016)
1.00	.669 (.017)	.549 (.019)	.358 (.015)

Anode Resistance. Two separate anodes were used. The first was 20 μm diameter gold-plated tungsten, which gave the counter a resistance of about 170 ohms. The second was 25 μm diameter gold-plated, stainless steel, which gave a total resistance of 1125 ohms. No clear relationship was found between anode resistance and position measurement, because the techniques used were not as developed when experimenting with the first anode as with the second. The position separation could not be increased with the second anode, but the resolution was cut in half. Again, this could be due to the improved handling of the system, not because of a change in resistance.

The anode change did affect the optimum capacitance for the system however, the optimum RC product for this system was found to be constant.

The first configuration was:

$$RC = (170 \text{ Ohms})*(.068\ \mu\text{F}) = 11.56\ \mu\text{s}$$

The second configuration was:

$$RC = (1125 \text{ Ohms})*(.010\ \mu F) = 11.25\ \mu s$$

The small discrepancy is probably a result of the limited choice of capacitors.

End Result. The optimum position separation and resolution that was achieved with this counter system is displayed in Figure 1. The current position separation is about 72% of its theoretical prediction, and the current resolution is about 1.6% of the full position spectrum.

Background Spectrum. A series of background runs (runs with no artificial event generation) were collected, one of which is shown in Figure 2. These background runs were normalized to hole 2 instead of hole 1 in order to center the spectrum. This particular run was collected for 19 hours, accumulating about 3800 events. The resulting spectrum was not the even distribution that was expected, and it did not cover the range that was predicted by the current position separation.

CONCLUSIONS AND RECOMMENDATIONS

Since capacitance affects the position separation more than any other parameter, the optimum capacitor should be found before any other parameter is varied. The pulse shaping times greatly affect both position separation and resolution, so they should be adjusted next. A "happy medium" must be found with the fast pulse time, because as the position separation increases, the resolution gets worse.

Setting the anode voltage as high as possible without saturating the amplifiers seems to give the best results.

The background spectrum is still a mystery. The peaks could be caused by a number of things, including defects in the anode wire at those points, defects in the counter wall at those points, and some fault of the electronic system. The contraction of the spectrum at the low end could be a result of physical attenuation of the pulse as it travels down the length of the anode.

With the position separation and resolution as they presently stand, it is possible to get a position measurement to the nearest 1/2 inch of the 3 foot proportional counter, which is more than satisfactory for the purposes of the Sudbury Neutrino Observatory.

We have fabricated a 6 foot long proportional counter that has a movable source inside it and is all metal sealed that will allow pressurizing to four bar internal pressure. This new counter is of a size more nearly like that proposed for SNO and we plan to test this counter in a similar manner to the tests presented here. We plan to run tests at higher pressures and with both P-10 and Helium.

SCINTILLATION COUNTING SYSTEM

We have contracted to have a small, metal sealed, UHV gas system fabricated. All of the components have been delivered and the final assembly is underway with delivery expected in September. This system will allow us to evacuate a sample cell or detector, then fill it with a gas mixture of interest while circulating the gas through suitable purifiers. We have received some of the components for the gas cell itself and are working on the selection of the type and size of optical window for the cell. We propose to measure the spectrum and scintillation efficiency of various gas mixtures using an optical multichannel spectrometer. We hope to be able to measure over a wavelength range of 180 to 700 nm, and may be able to couple the gas cell to the spectrometer via optical fiber. We have sent out an RFQ for this system and expect delivery before October.

DIAGRAM 1. Counter System

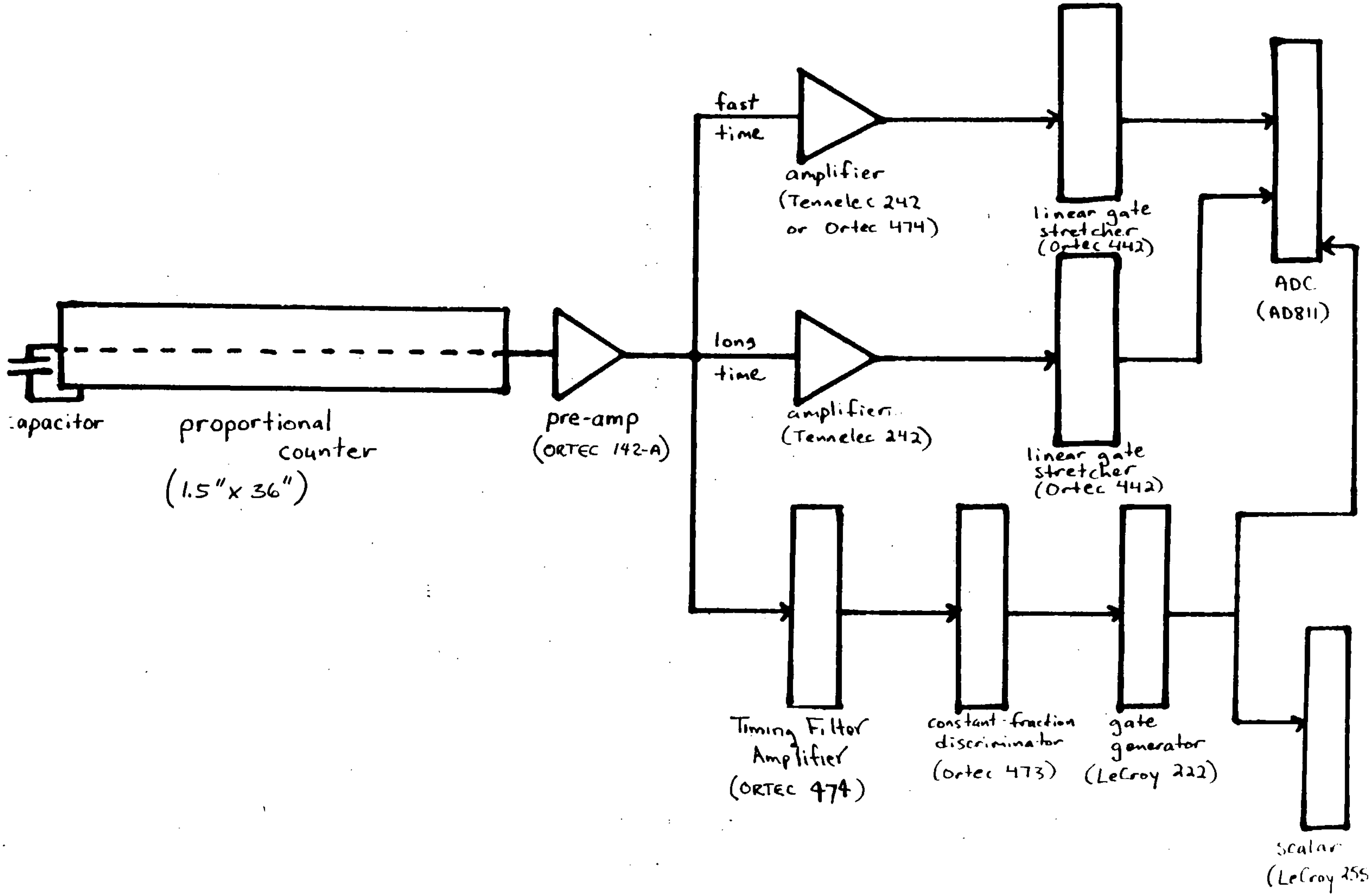


Figure 1. Optimum result

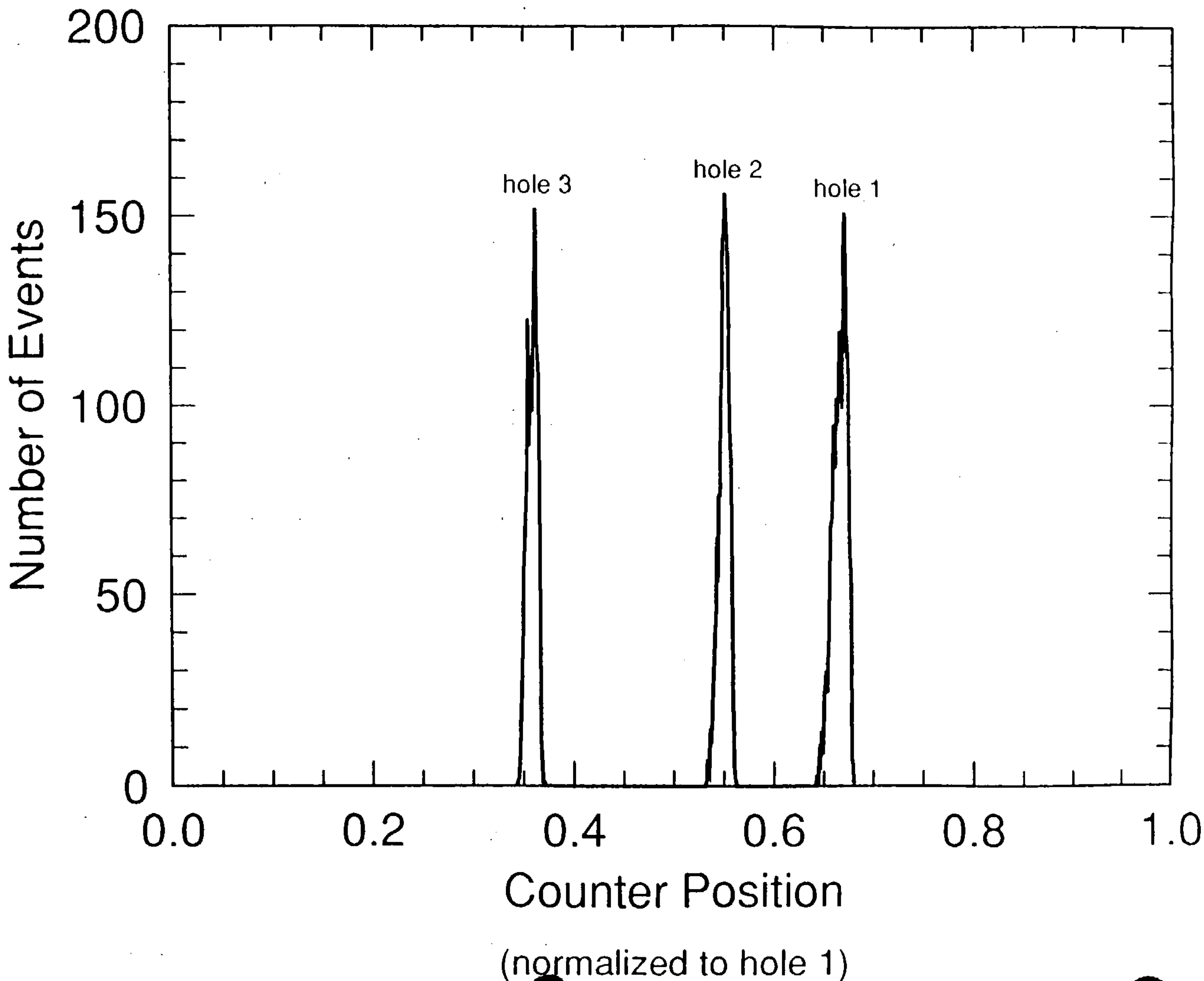
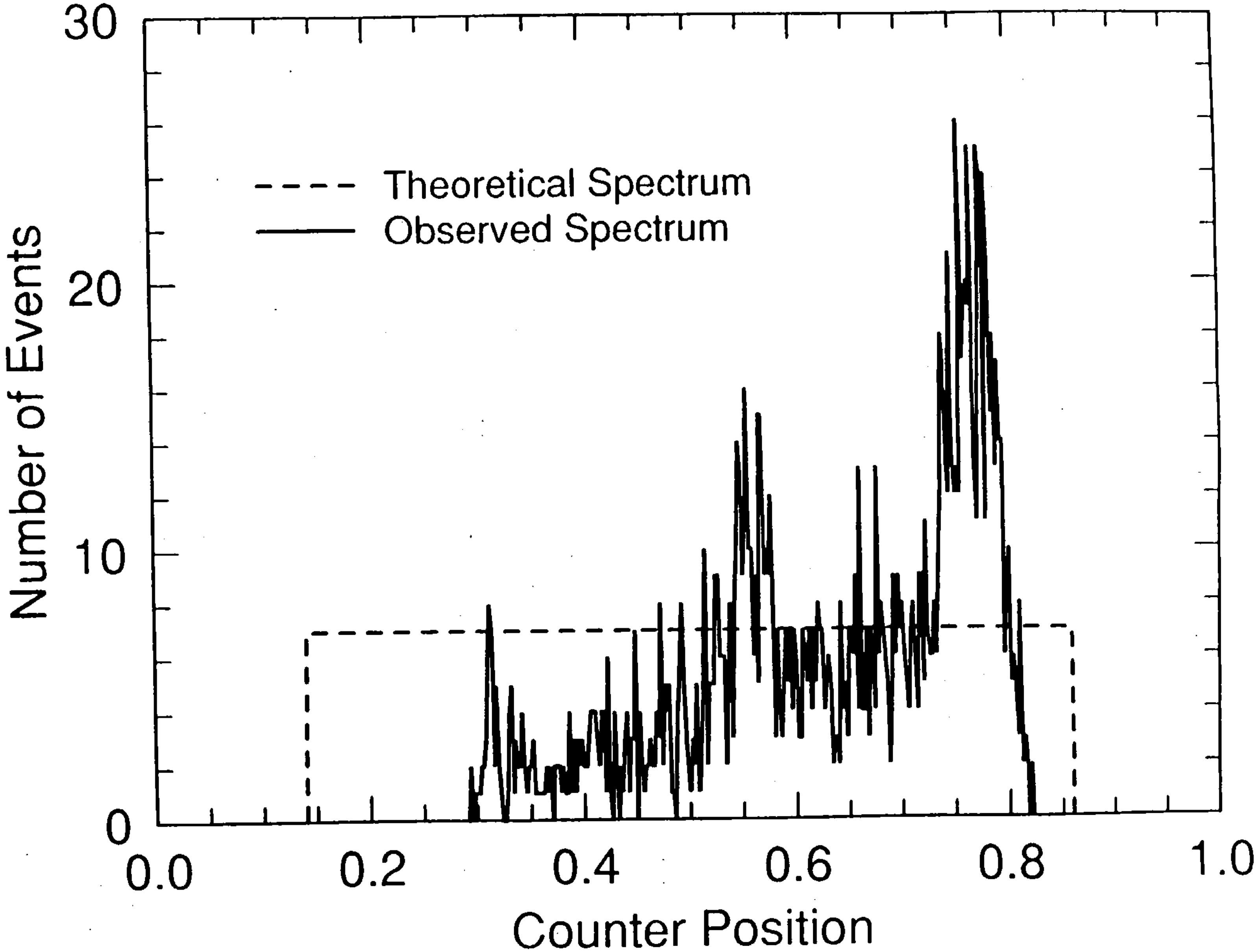


Figure 2. Background Position Spectrum



(normalized to hole 2)