Summary on the Electron Beam Position Control and Photon Flux Monitoring Test Run Made on March 22-26, 2010

Dr. Dale's group.

Our main goals for the run were to:

(1) Establish beam with collimator hole blocked, 2 degree kicker off. 900 Hz, shortest pulse width possible, whatever current needed to tune up beam. Use segmented Faraday cup with this, so check signals and noise on this at this point. Also use view screen here.

(2) Unblock collimator hole, ramp up current and survey.

(3) Calibrate kicker magnet deflection using view screen.

(4) Cross calibrate view screen and segmented Faraday cup.

(5) Pair spectrometer test without converter for three orientations of 2 degree kicker.

(6) Pair spectrometer rate tests with converters, three kicker magnet positions.

The original geometrical configuration of the experimental setup used at the beginning of the run was the following:

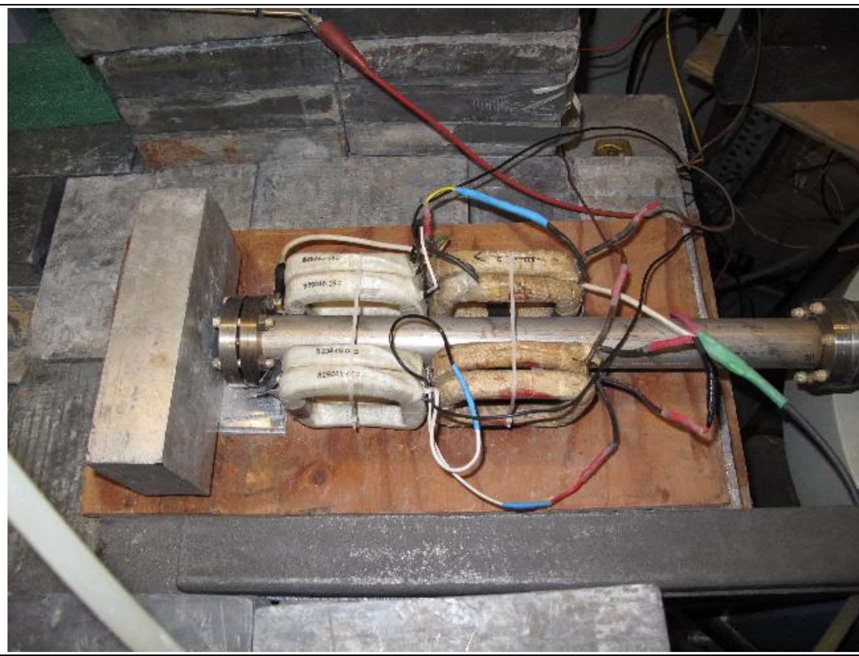


Figure 1: 2 degree kicker magnets placed 2.5 cm upstream of the 1 mil Ti radiator.

Figure 2: The kicker magnet power supply and monitoring camera placed behind lead shielding.

Figure 3: A 12-inch thick off axis collimator at m/E beam right, delta theta m/(2E).

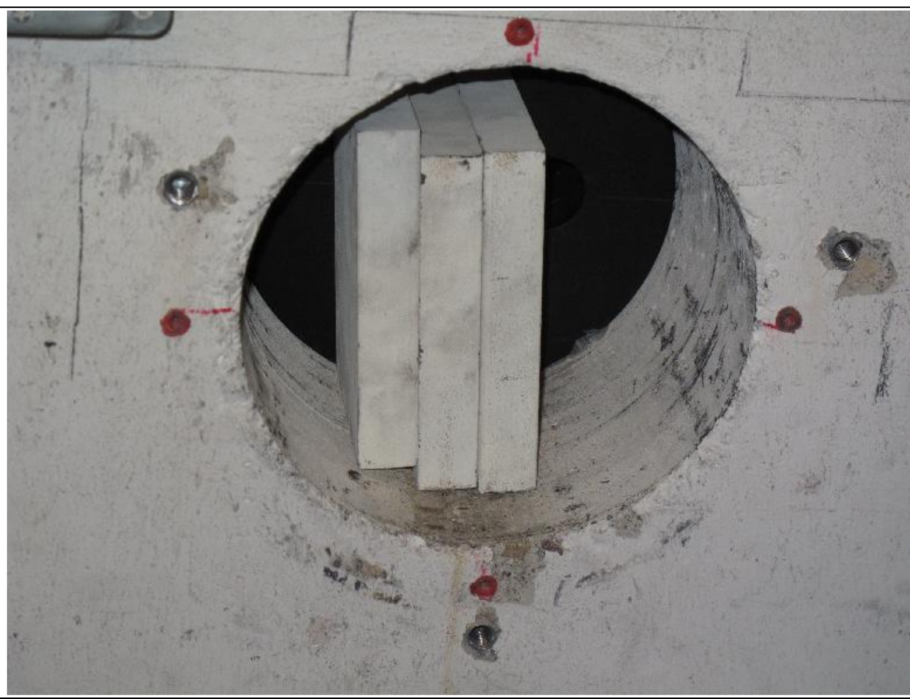


Figure 4: 10 cm of iron blocking the central hole of the 12-inch thick off axis collimator.

Figure 5: Neutron shielding added.

Figure 6: 2-inch thick graphite shielding with off axis hole downstream of the Faraday cup.

Figure 7: Segmented Faraday cup composed of 16 stacked aluminum bricks just upstream of shielding wall on accelerator side, view screen attached to upstream side of that with camera placed next to the kicker magnet.

Figure 8: General view of the accelerator side setup.

Figure 9: 6-inch thick neutron shielding with off axis hole placed downstream of the 12-inch thick off-axis collimator.

Figure 10: An 8-inch copper brick was used to cover the central hole of the 12-inch thick off-axis collimator. The rest of the space in the hole of the concrete wall was filled with borated polyethylene without covering the off axis collimator hole.

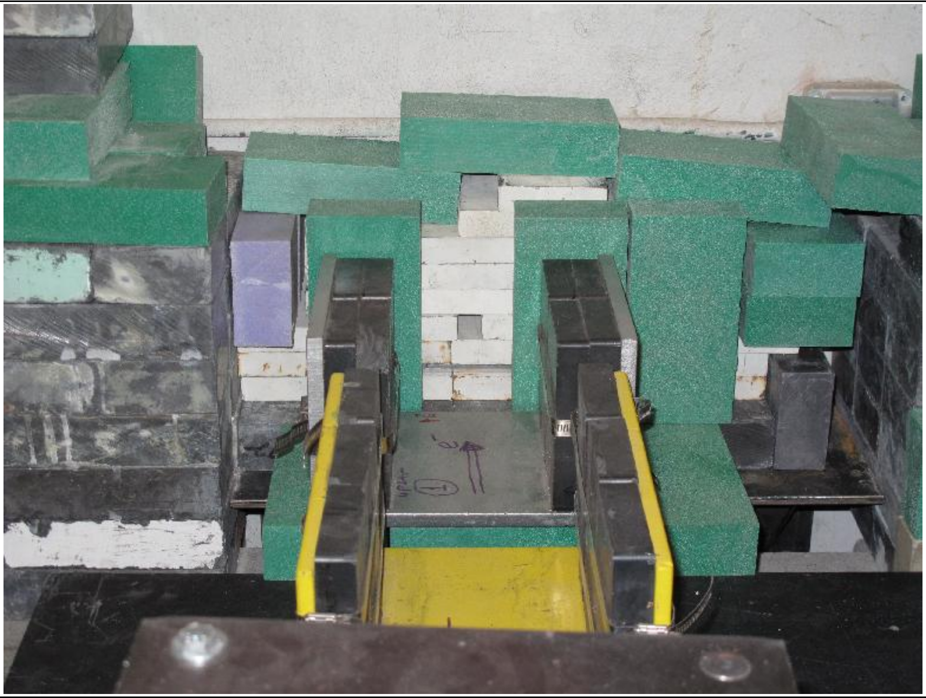


Figure 11: Off-axis iron collimator (10cm x 1'' x 1'') was placed just downstream of the concrete wall on the experimental cell side. Two sweep magnets placed downstream of the iron collimation, sweeping vertically.

Figure 12: Pair spectrometer with Max and Ilyusha (not shown) set downstream of the sweep magnets.

What's been achieved during the run:

Radiation survey carried out at the beginning showed that electron flux going to the experimental cell was over the acceptable limit. To reduce the flux of the electrons we blocked off axis collimator hole with 2'' of graphite placed inside the beam line shielding at the accelerator side next to the Faraday cup. Additional shielding made consisted of 2-inches of aluminum, lead and parowax placed on the top of the sweeping magnets.

As a first test we observed the signal from one aluminum brick of the Faraday cup using oscilloscope (see Figure 13). A square trigger pulse was matched in the time of the Faraday cup signal shown. The electron beam current was 2 mA and a rep. rate of 900Hz.

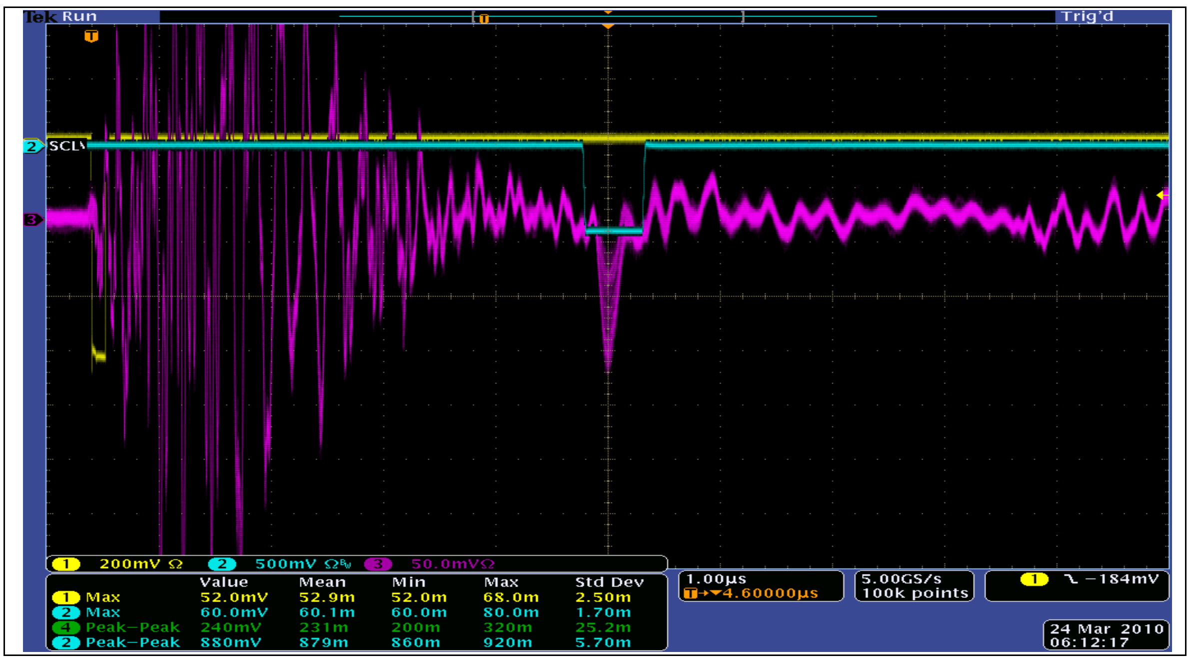


Figure 13: Analog signal from the Faraday cup (single channel).

Then, the Faraday cup was connected to a 16 channel ADC (0-15 channels). The spectrum of the signals from all the blocks of the cup was observed for different currents of the kicker magnet and the two different polarities of the magnet power supply. In Figure 14 it is shown that the ADC spectrum of the beam position for the current of 5 amps on the kicker magnet and the beam is bent downward. The 16th channel corresponded to the top aluminum brick of the Faraday cup.

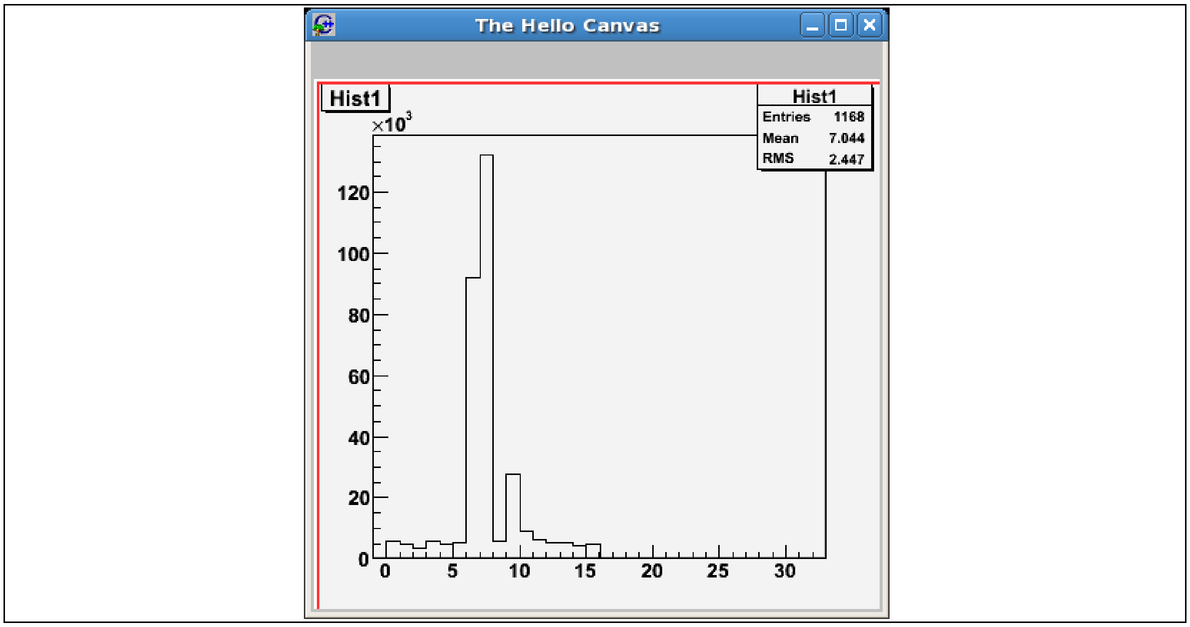


Figure 14: ADC spectrum of the beam position for the current 5 amps and the beam bent downwards.

One can see the maximum in the spectrum is shared between 6th and 7th bricks.

In the Figure 15, the ADC spectrum of the beam position is shown for the current of 5 amps on the kicker magnet and the beam is bent upwards.

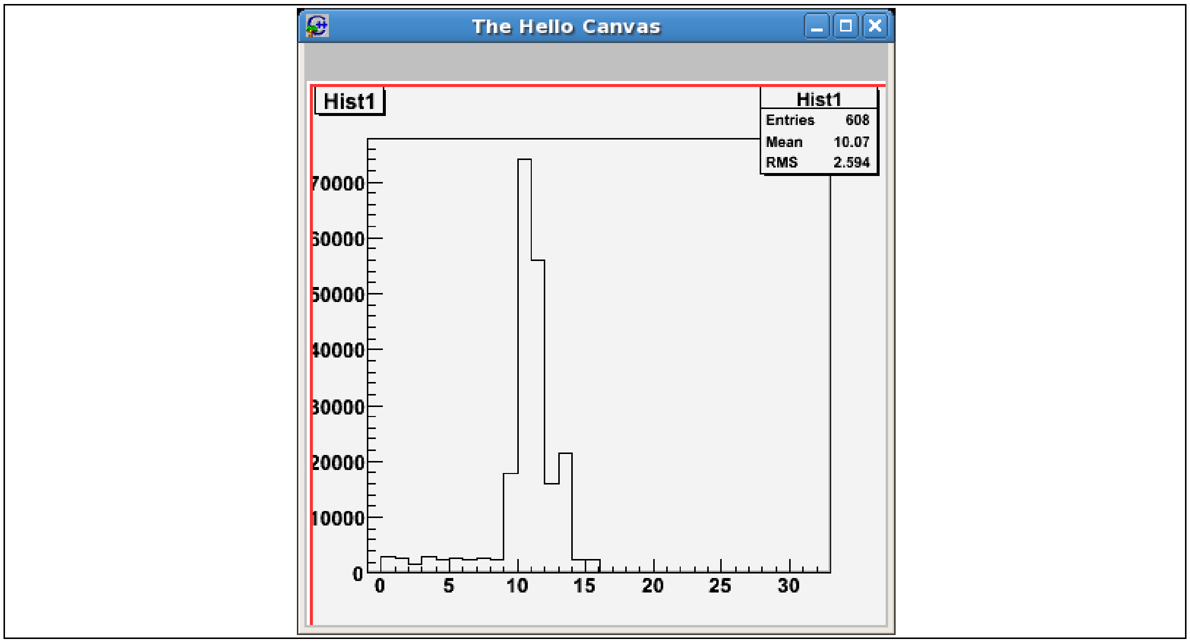


Figure 15: ADC spectrum of the beam position for the current set at 5 amps in the beam-up position.

One can see in the spectrum the maximum is shared between 10th and 11th bricks.

The ADC spectrum for the beam without deflection (zero current) is presented in Figure 16 below.

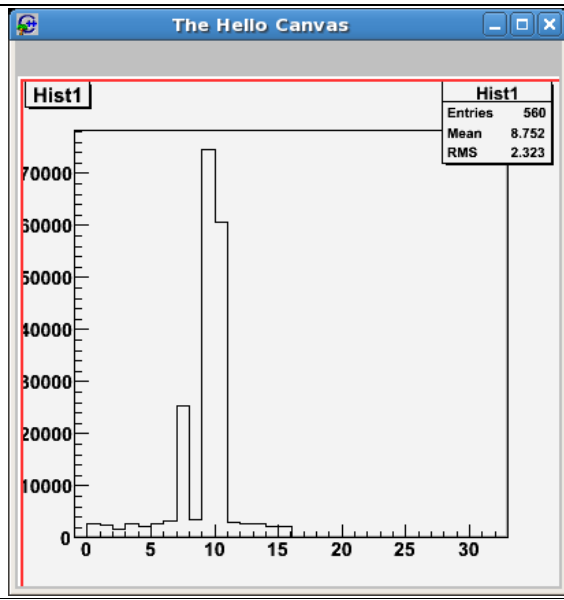


Figure 16: The ADC spectrum for the beam without deflection (zero current).

One can see the maximum in the spectrum shared between 9th and 10th bricks.

However, these measurements couldn't tell us more precisely the position of the beam because of the specific features of the read out electronics that were oriented to writing data to files and not to graphical on-the-fly representation. Processing the data files gave the plot shown in Figure 17.

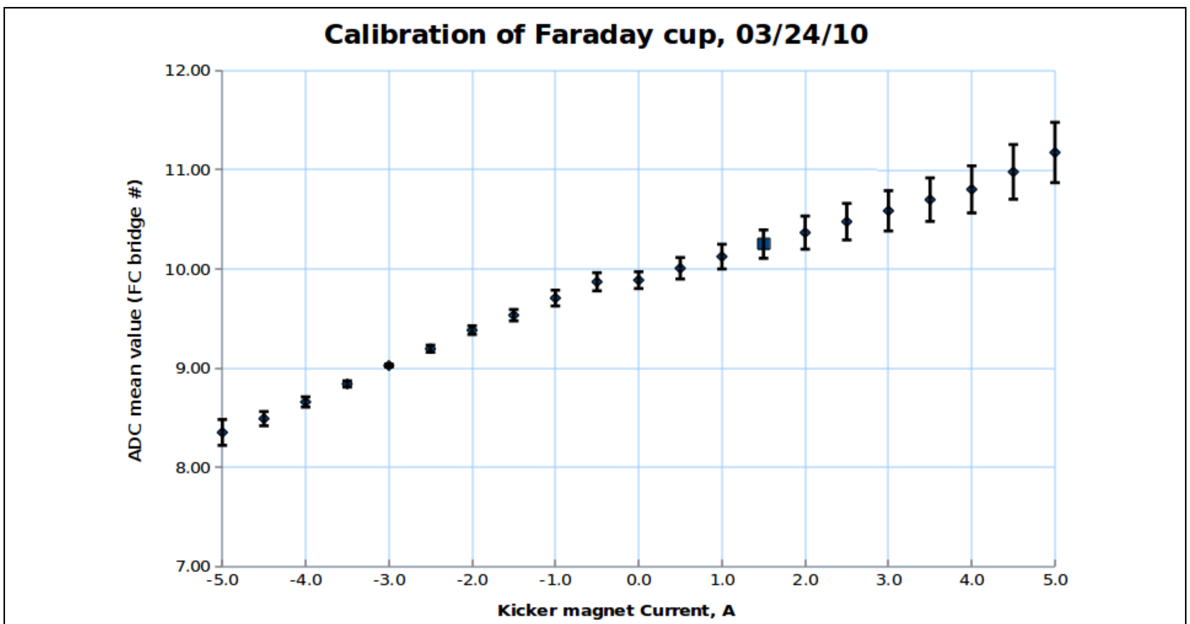


Figure 17: Faraday cup calibration as a function of Kicker Magnet current (Roman).

Next, we matched the thresholds of two detectors used as a part of $e^{\pm}$ spectrometer. We made a telescope (back-to-back placement) of these two detectors, as shown in Figure 18 below, and placed it on the e^- side of the spectrometer. An additional μ-metal shielding was wrapped around the voltage dividers and phototubes to prevent the magnetic field of the spectrometer from interfering with electron current in phototubes.

Figure 18: Setup used to match the thresholds of the two detectors.

Using the measured timing spectrum we were able to define the ratio of the coincidence peak area to background integrated over a certain region of the spectrum. The electron beam was bent down and counting period was 500 seconds. The results are shown below.

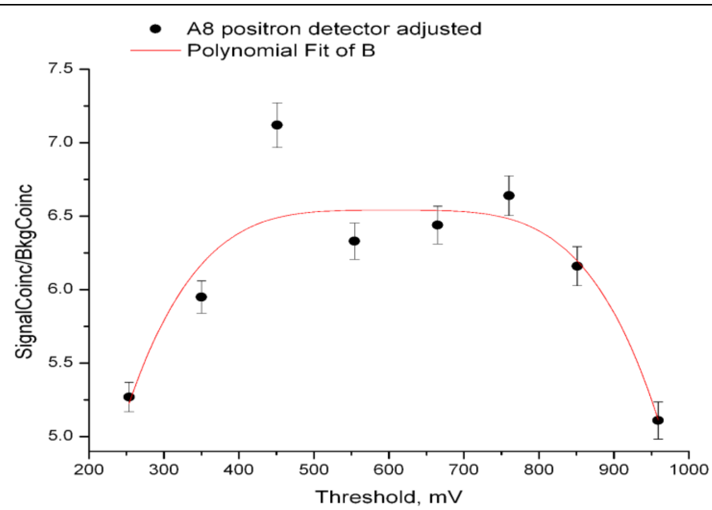


Figure 19: The e^+ detector threshold being changed while e^- detector threshold kept constant.

The threshold was set at 550 mV for the e^+ side detector.

Next we did the same procedure for the e^- side detector with the adjusted threshold of e^+ side detector. The results are shown in Figure 20.

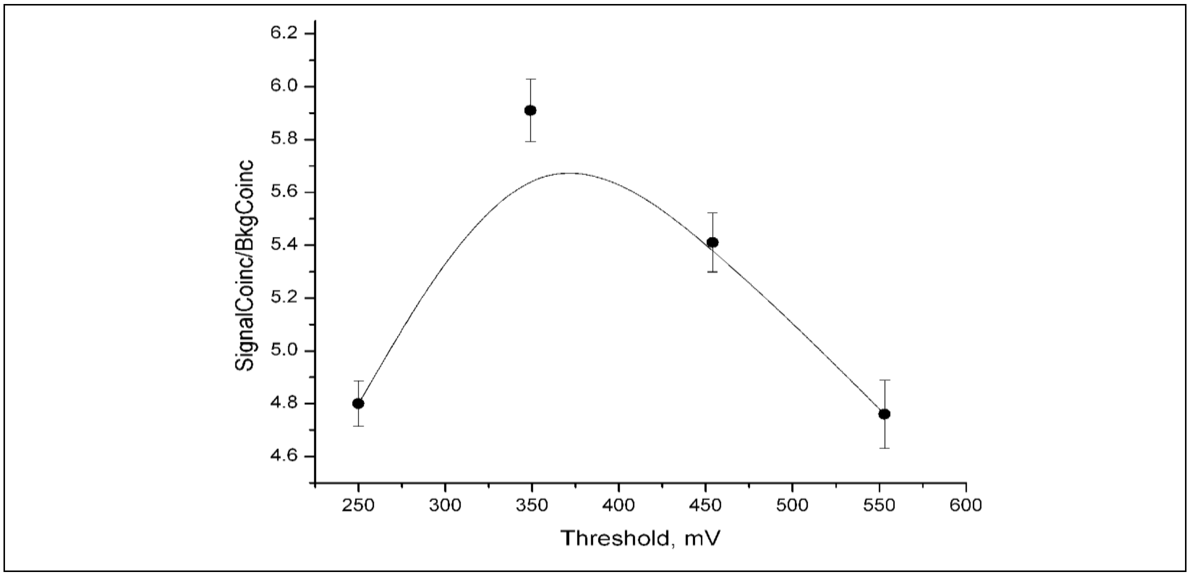


Figure 20: The e^- detector threshold being changed while e^+ detector threshold kept 550 mV.

The adjusted value of the threshold of the e^- detector was set to 355 mV.

After the threshold matching procedure we tried to obtain a timing spectrum of real $e^\pm$ coincidences using polarized photons. The detectors were placed on both sides of the pair spectrometer to cover forward angles (~10 MeV region). The aluminum converter was 1 mm thick. We used coincidences between the trigger pulse and positron signal as a start for the time-to-amplitude converter (TDC) signal. The whole range of TDC was 200 nanoseconds. The electron signal was used as a stop signal for the TDC. Also, an additional vertical collimator (5 mm width) was placed downstream from the iron collimator at the experimental cell to reduce room background. The timing spectrum with the coincidence peak at the expected position is presented below in Figure 21. The beam, which was bent down by 5 amps, had the current set to ~3 mA peak value; electron energy was 14 MeV; pulse width 50 ns; frequency 900Hz.

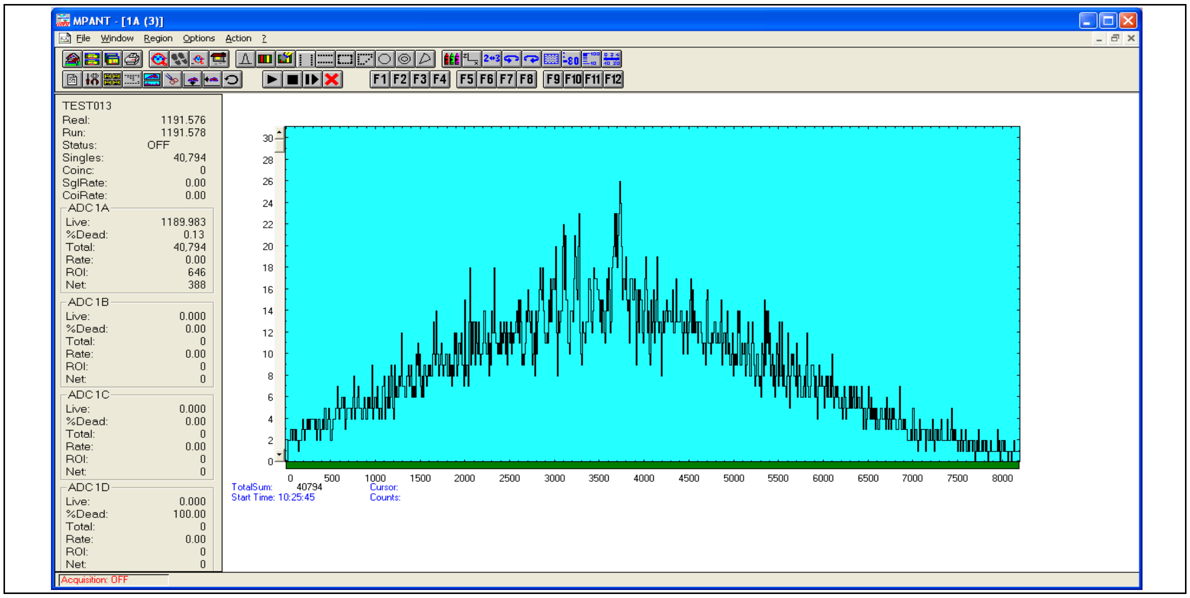


Figure 21: Timing spectrum.

Some structure can be seen in the timing spectrum above which was probably caused by the electronics (start-stop TDC pulses jitter, etc.). The peak in the center of the spectrum is supposed to be the real $e^{\pm}$ coincidence peak. We tried to improve the timing spectrum by opening up the collimation. The copper collimator was removed, but the 1 inch by 1 inch iron collimator was left in place. Then, 30 layers of aluminum foil were used as the pair converter. The spectrum is presented below in Figure 22.

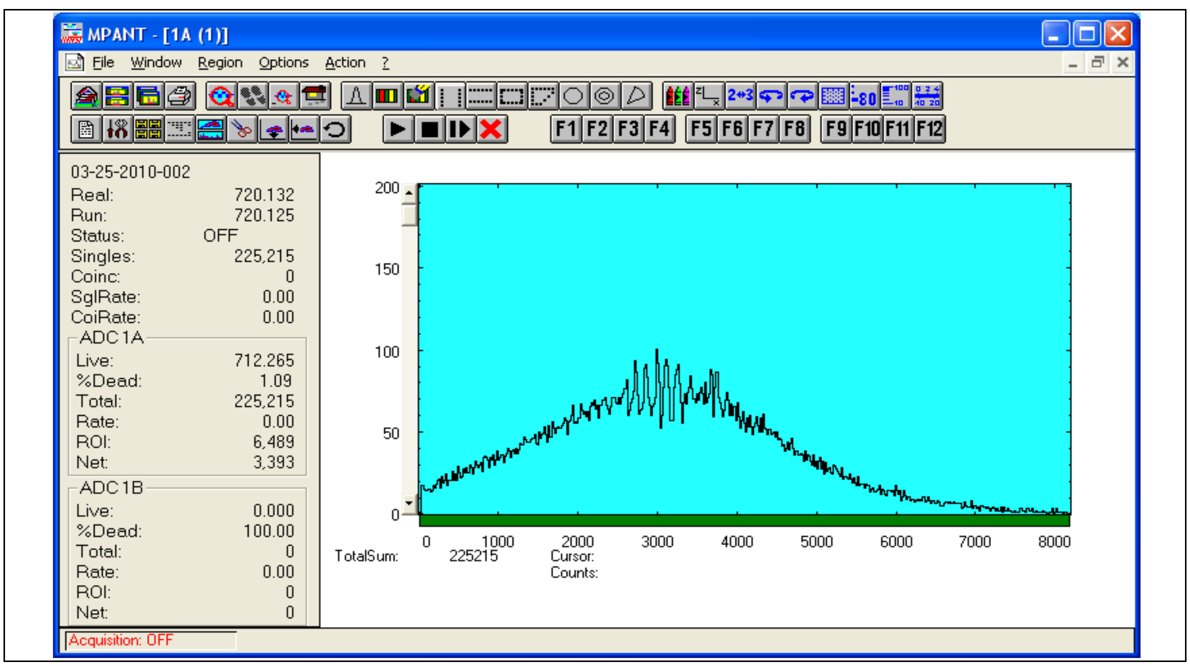


Figure 22: The spectrum obtained when the copper brick was removed and a thicker converter was placed.

As can be seen from the spectrum above, there was not a significant improvement. The structure is still present and the counting rate was 313 Hz.

Next, we reduced the converter thickness to just 10 layers of aluminum foil. The spectrum is presented below in Figure 23.

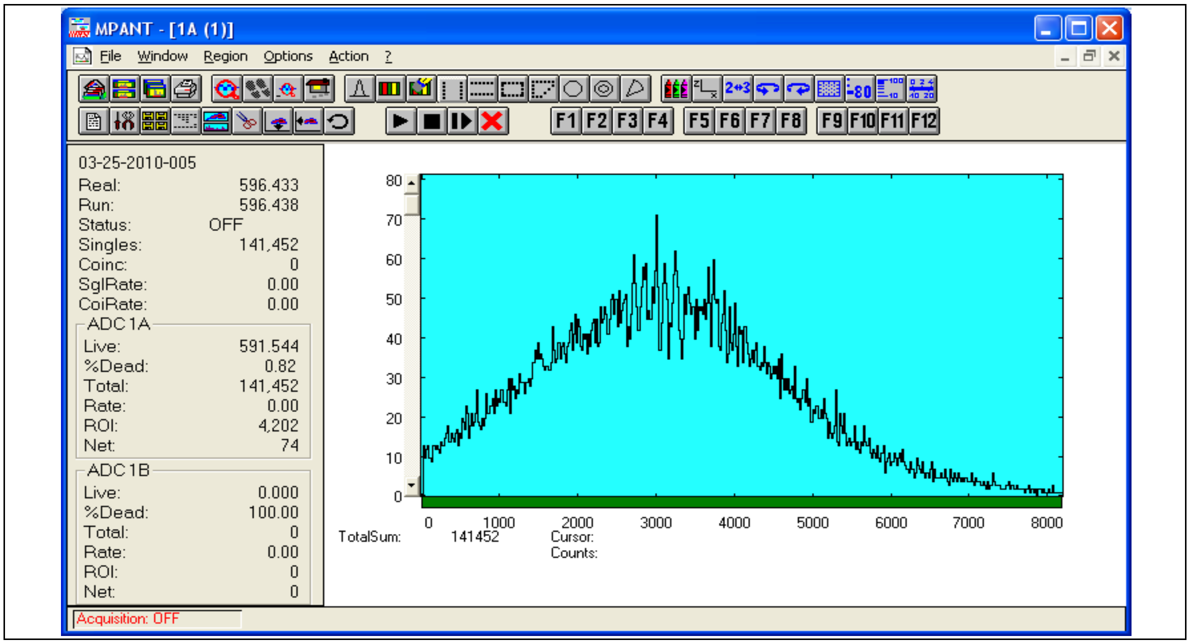


Figure 23: Spectrum from 10 layers of Al foil and not copper collimation.

The counting rate was reduced to 240 Hz. Next, the detectors' positions were changed to detect low energy pairs (bent by 90 deg w.r.t. the beam line). The timing spectrum is shown below in Figure 24.

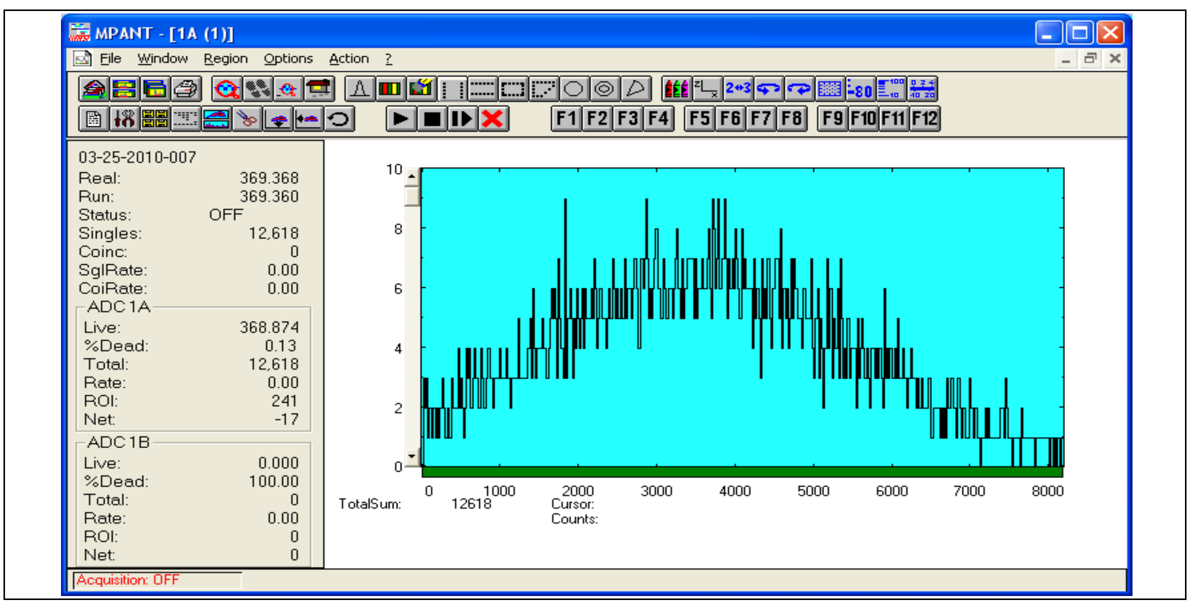


Figure 24: Spectrum obtained after moving the detectors upstream as to detect lower energy pairs.

The counting rate was reduced to 34 Hz.

Then, we changed the thresholds on the detectors and the linear discriminator output pulse widths to get rid of the structure in the timing spectrum. The detectors were shielded better and an additional lead collimator (~5mm) was placed just upstream of the pair converter (30 Al layers). As a result, we got the spectrum shown in Figure 25.

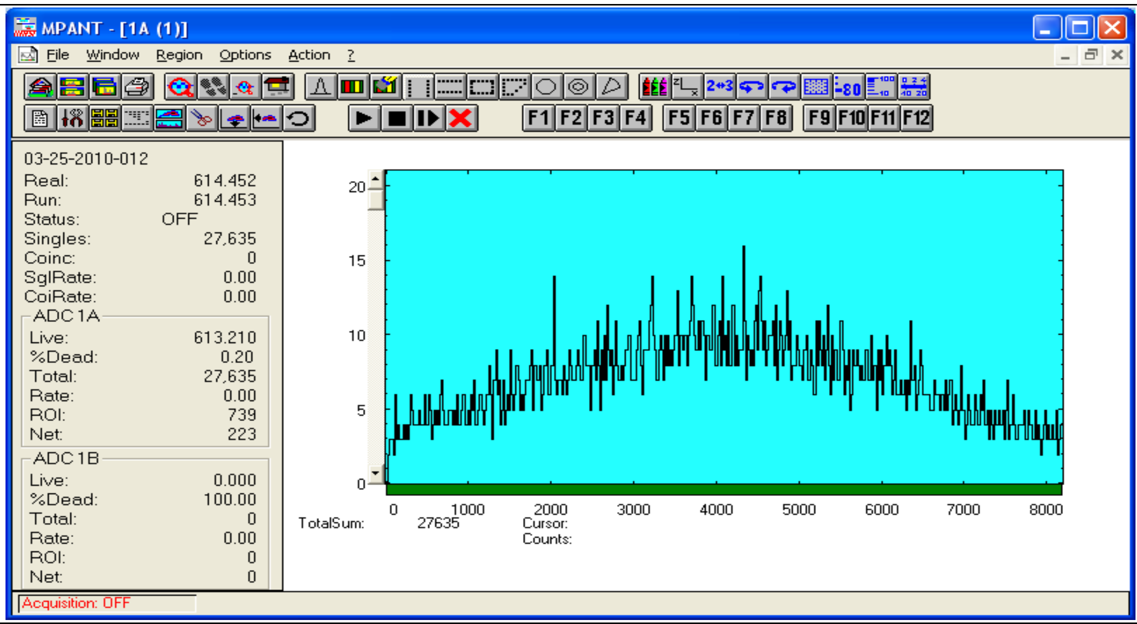


Figure 25: Spectrum obtained after the detectors were shielded better and a lead collimator was put in place.

This resulted in the loss of the structure, but there is still no coincidence peak in the timing spectrum.

Dr. Dale suggested trying a one armed photon flux monitor based on the detection of e^+ coincidences by a detector telescope. The main source of positrons in the experimental cell is considered to be from pair production in the pair converter.

Figure 26: Setup used to detect e^+ coincidences.

The example of the timing spectrum obtained from a 5 mA beam current (the rest of the parameters are the same) is presented in Figure 27 where the only collimation used was the 1 inch by 1 inch iron collimator.

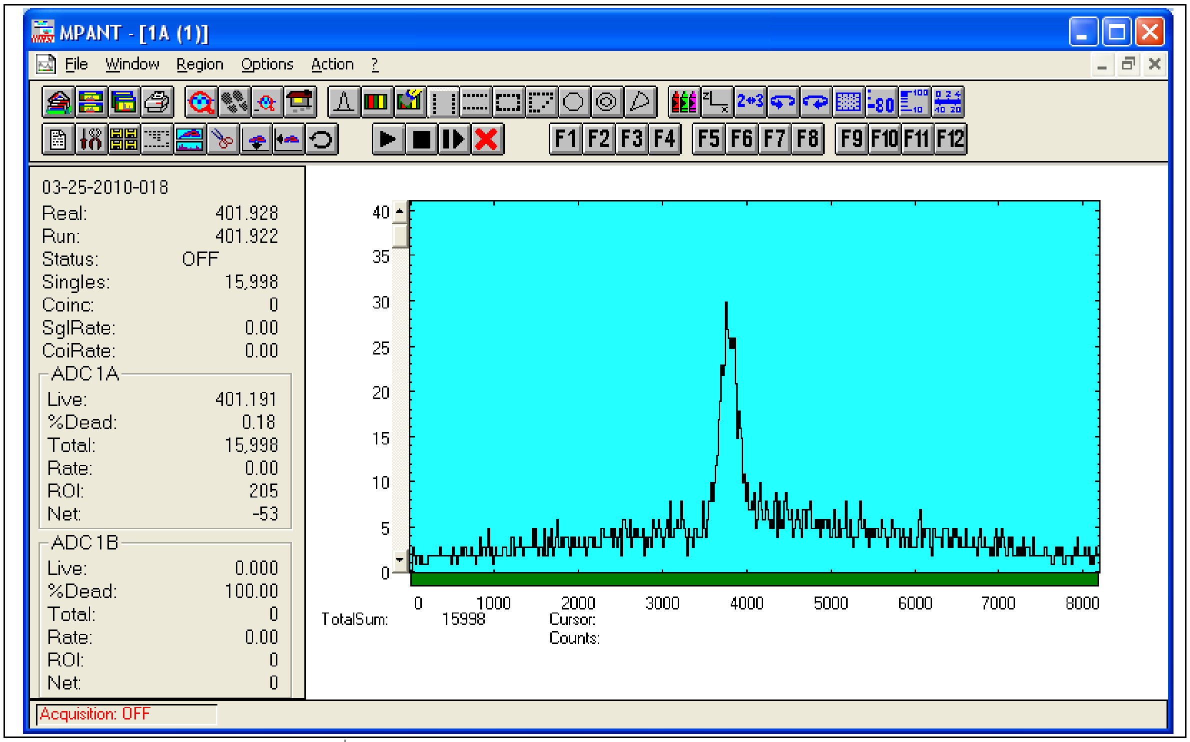


Figure 27: Spectrum of the e^+ coincidences.

We obtained a counting rate of about 9 Hz in the e^+ coincidence peak. The timing resolution in the coincidence peak is ~ 5.45 ± 0.12 ns. Singles counting rate was 40 Hz.

Conclusions:

During the run we made a test of the kicker magnet operational conditions. We observed the beam spot on a view screen via camera which was changing its position in vertical direction under the change of the magnet current.

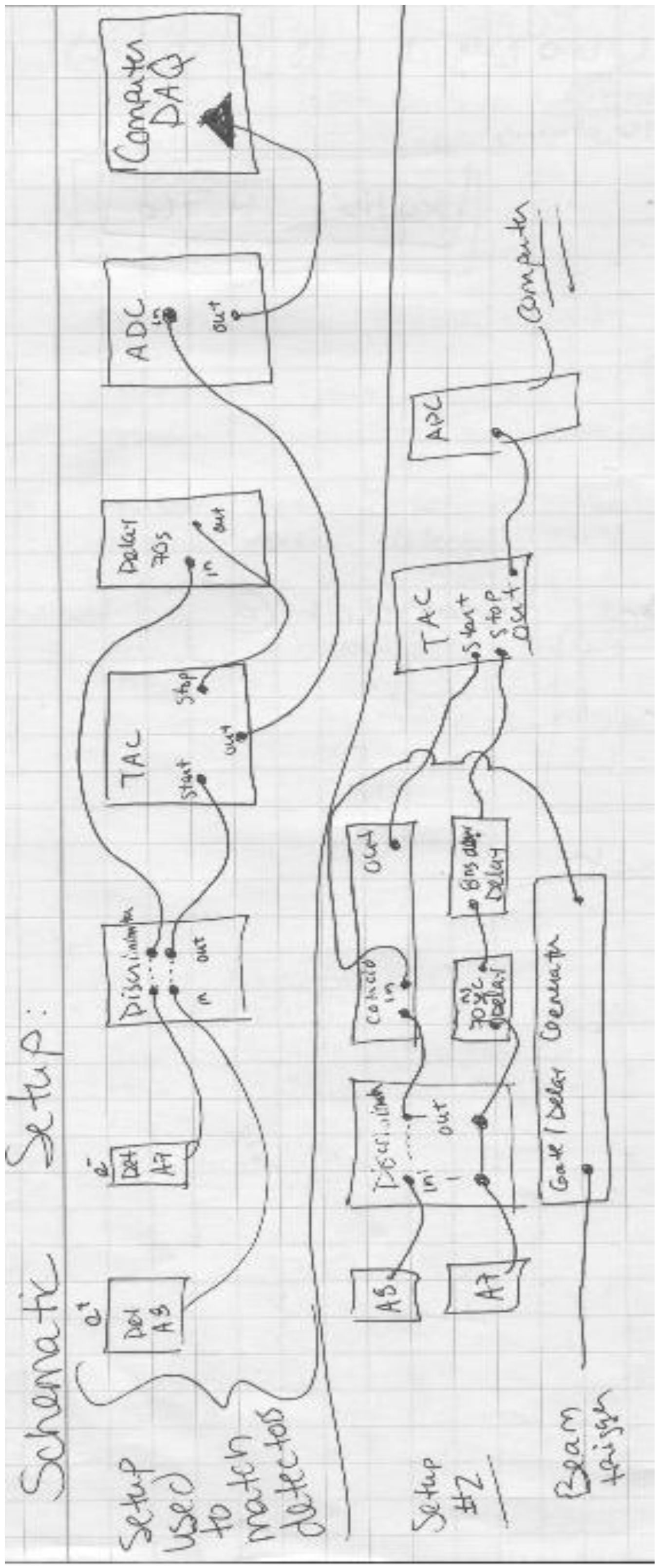
An analog signal was observed from all the Faraday cup's single segments. An ADC spectrum was obtained for all the segments. Calibration of the beam position as a function of magnet current was made.

The decision has been made to use the detector telescope in the positron side of the pair spectrometer in order to obtain the information on the photon flux.

Additional calculations and measurements are needed to calibrate the pair spectrometer in terms of detector placement, positron energy and number of photons, and number of positrons.

The counting rate in the positron coincidence peak will tell us what the photon flux of photons of a particular energy is. The energy of the photons will be defined by the position of the telescope.

Appendix:



Experimental setup principal design.