Recreating the CRaTER SN01 (FM2) D2 Anomaly with the Engineering Model

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1. HISTORY

The D2 anomaly was first observed during proton beam testing at Massachusetts General Hospital (MGH) on November 4, 2007. It is described in depth in Justin Kasper's original report on the matter ("2007-005 SN01 D2 Anomaly.pdf").

There were two main manifestations of the issue. Firstly, there was an apparent decrease in the gain of D2. The magnitude of the decrease in gain also appeared to change as a function of time (See Figure 1). The change in gain did not appear in pulser data. Secondly, the D2 singles rates showed extremely high count levels with the detector bias on, but much lower count rates with the bias off.

The instrument was then returned to MIT, where the problem was seen using a Co-60 source (See Figure 2), and persisted for approximately a day before apparently resolving itself.

2. TROUBLESHOOTING FM2

On November 8th, troubleshooting commenced with Bill Crain from Aerospace and the MIT engineering crew (Jimmy, Dorothy, Bob, Matt, Rick) present at MIT. It was found that there was a resistance across the connector where D2 attached to the telescope board causing the detector to not be fully biased (See Image 1).

Upon further investigation, it was discovered that conformal coating had found its way into the D2 connector and was causing the observed drop in voltage across the connector (See image 1). The telescope board was removed and taken back to Aerospace with Bill so that the board-side connector could be replaced, while the rest of the telescope remained at MIT for further inspection.

3. RECREATING THE ANOMALY WITH THE EM

An Airborn connector (MA-2E1-004-433-A00-00), identical to the one used in the CRaTER telescope assembly to connect detector and telescope board, was removed from a test board. The barrel and pin sides of the connector were separated and oriented back-to-back. The detector ground and junction pins on the two connector halves were jumpered with small wires soldered between the respective external leads. The HV bias pins were connected via a small potentiometer soldered between the respective external leads. On the EM, the D4 detector-telescope board connector was then separated and the modified connector assembly inserted between the two connector halves to complete the connection. This configuration allowed the resistance across the connector to be systematically modified and measured (via portable DVM) while also allowing the detector output to be monitored and processed as normal through the analog and digital chains and written to archive files via the normal Ballard Box-PC interface (See Images 2 and 3 and Figure 3).

It was noticed that there was interference from a light leak which was promptly fixed. Data were acquired at 0, 23.3kΩ and 50kΩ and it was found that non-zero resistances across the connector caused a considerable decrease in the apparent gain of D4. The decrease was consistent with observations of the anomaly from the flight model at MGH and MIT (See Figure 4). At the higher resistance, the apparent decrease in gain was more pronounced.

Singles rates were also measured at the 3 resistance settings with the bias on and off. It was found that the D4 singles rates behaved in a fashion similar to that observed during the flight model anomalous behavior. That is, with a resistance across the connector, the D4 singles increased when the bias was switched on. Without resistance across the detector, singles rates behaved as expected (See Figure 5).

4. CONCLUSIONS

The presence of conformal coat in the D2 HV bias line connector on CRaTER FM2 (SN01) appeared to cause a resistance across the connector of ~25 kΩ. Testing done on the engineering model indicates that a resistance of that magnitude can cause changes in the apparent gain and singles rates that are consistent with the anomaly observed in the flight model at MGH and MIT.

In the flight model, it was observed that the apparent gain in D2 changed over time. This feature has not been reproduced in the engineering model. The change in gain could be explained by some time-dependent electronic process(es) or a simple change in the resistance across the connector. It should be noted that the gain did appear to drift downward during a single data acquisition where there was no contact with the instrument (See Figure 6).

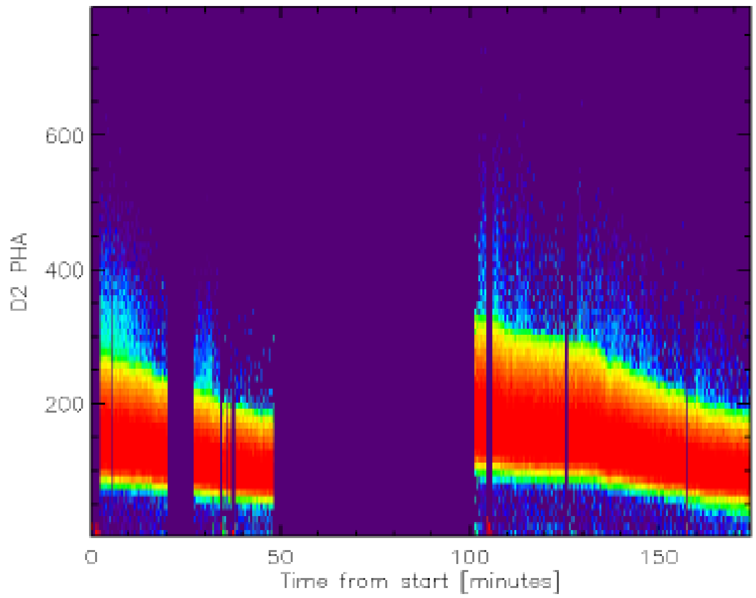
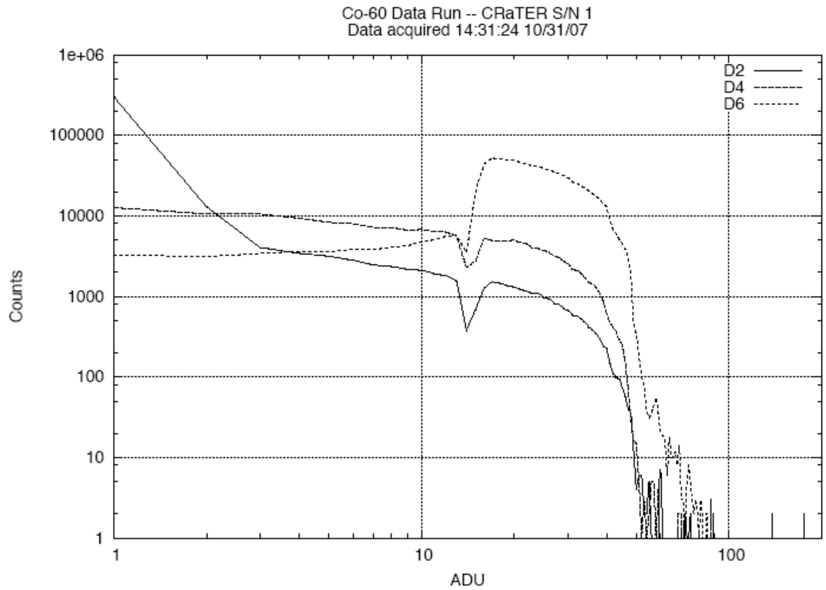


FIGURE 1: 2-D histogram showing the pulse height of D2 vs. time during a proton beam run at MGH. The peak deposit in D2 is expected to be in approx. 500-600 ADU, but appears around 300. It is also seen that the apparent gain of D2 changes over time. Data gaps occur when data was not being acquired.



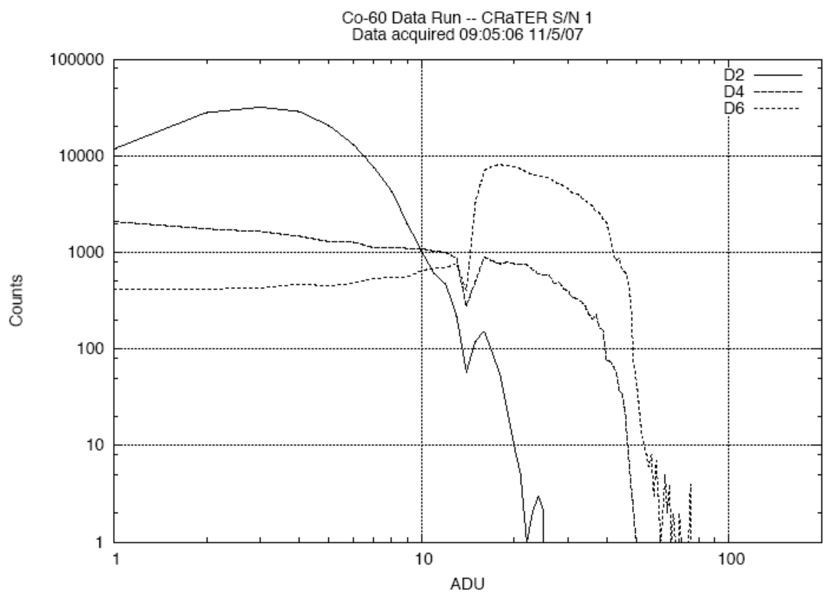


FIGURE 2: Top Panel: Co-60 run from Bob Goeke prior to the appearance of the anomaly. All detectors look similar (except for count rate, due to source location).

Bottom Panel: Co-60 from Bob Goeke after the MGH run. The apparent change in gain is clear in D2.

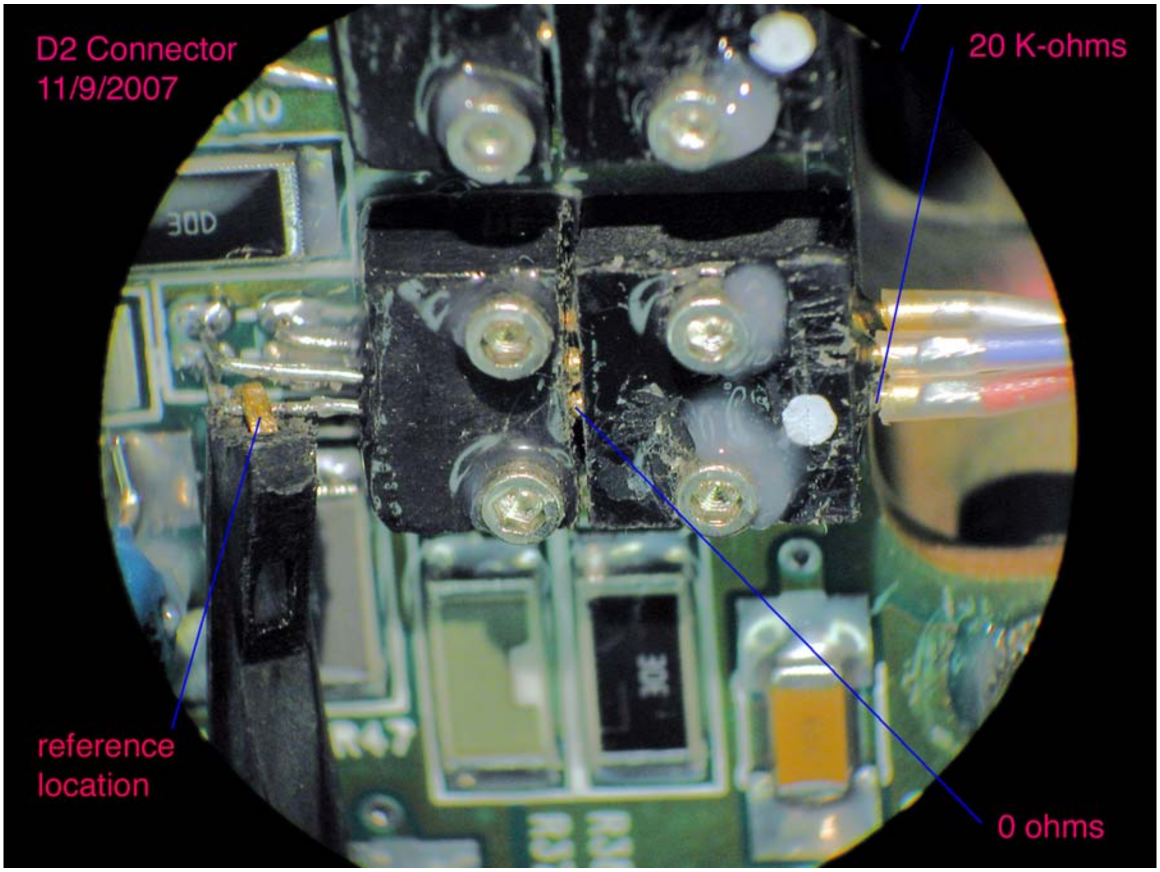


IMAGE 1: Microphotograph of the FM2 (SN01) D2 connector on the telescope board. It was found that there was conformal coat in the connector causing the observed resistance across the connector.

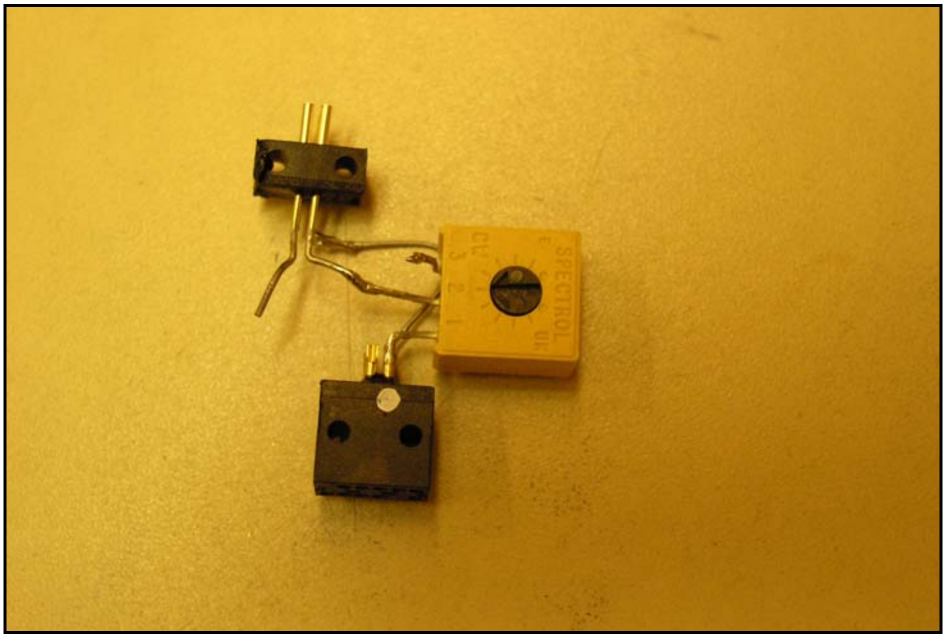


IMAGE 2: A connector designed to simulate the resistance caused by conformal coat in the HV bias line. It was formed from spare connector parts and a potentiometer.

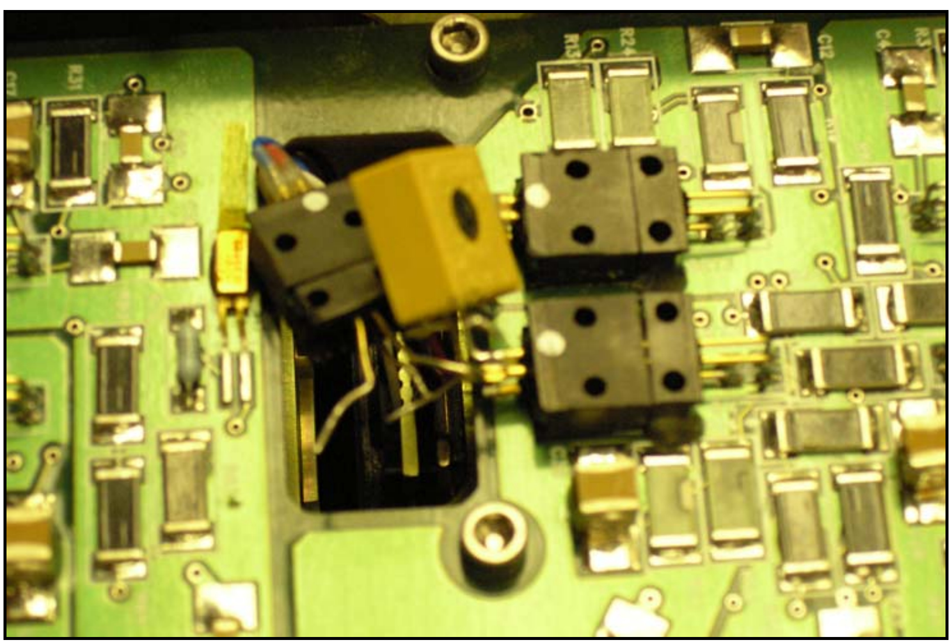


IMAGE 3: The connector installed on D4 of the engineering model.

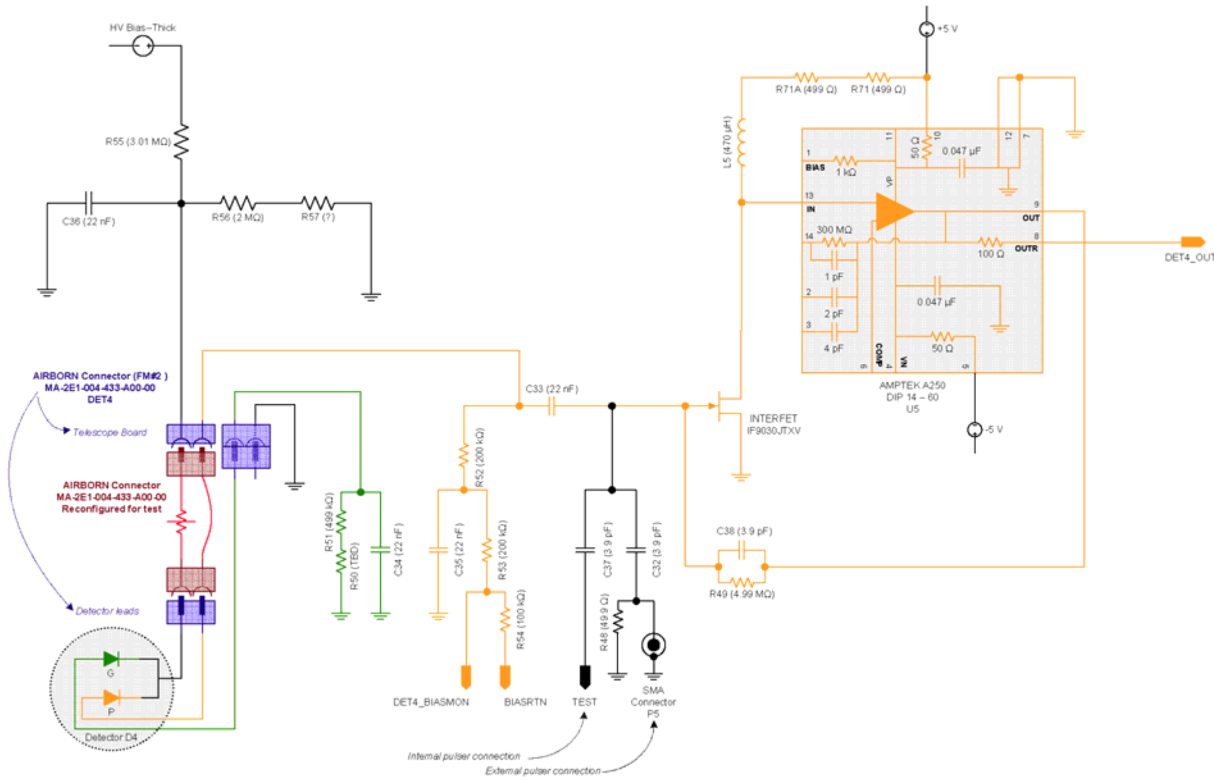


Diagram adapted from drawing
"CRaTER TELESCOPE BOARD Thick Detector #4 Preamp"
(DWG # 32-03005 Rev 0, 10 May 2006, sheet 5 of 7)

FIGURE 3: A schematic of the telescope board setup as used in testing.

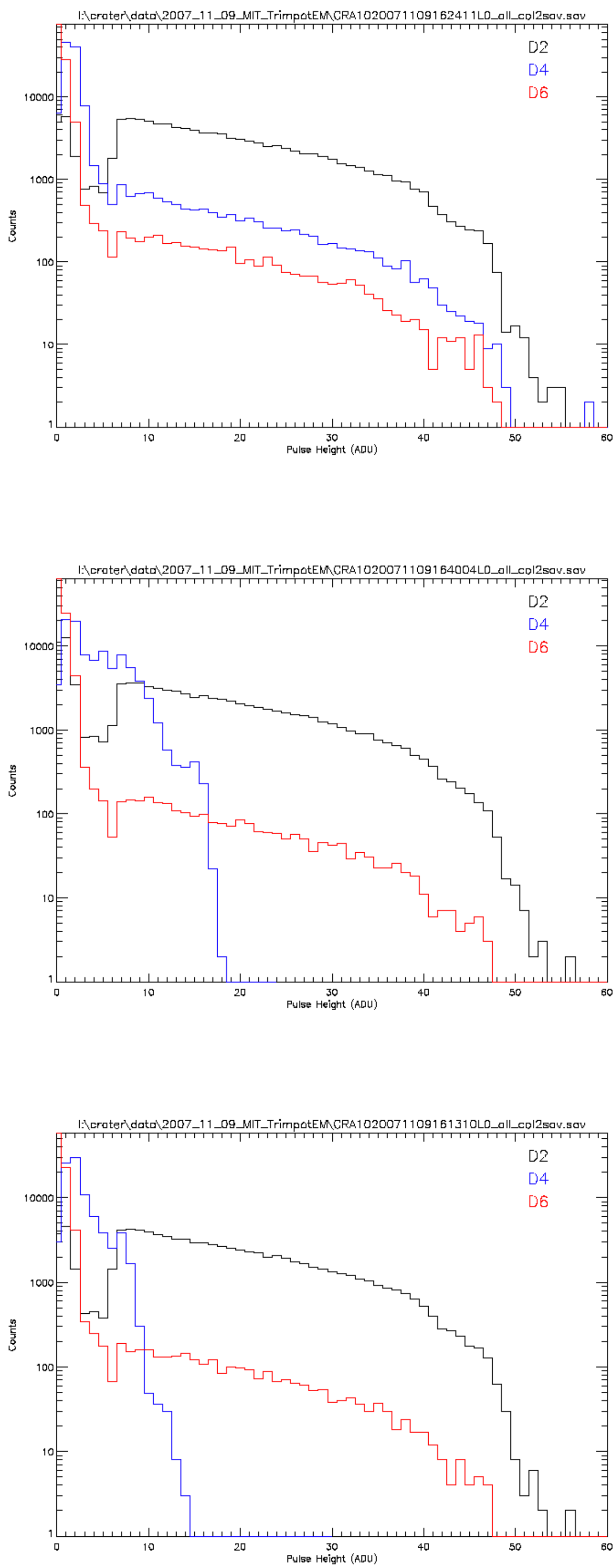


FIGURE 4: Thick detector histograms with potentiometer in-line on detector 4 of the EM. A Co-60 source is present on the zenith (D2) side of the telescope.

Nominally, all the detectors would have similar shapes (though count rates will differ since the source is at one end). This is seen in the top panel (no resistance across connector), but when a resistance is introduced (middle and bottom panels), the apparent gain of D4 changes.

Top Panel:
Potentiometer set to 0.

Middle Panel:
Potentiometer set to 23.3kΩ

Bottom Panel:
Potentiometer set to 50 kΩ

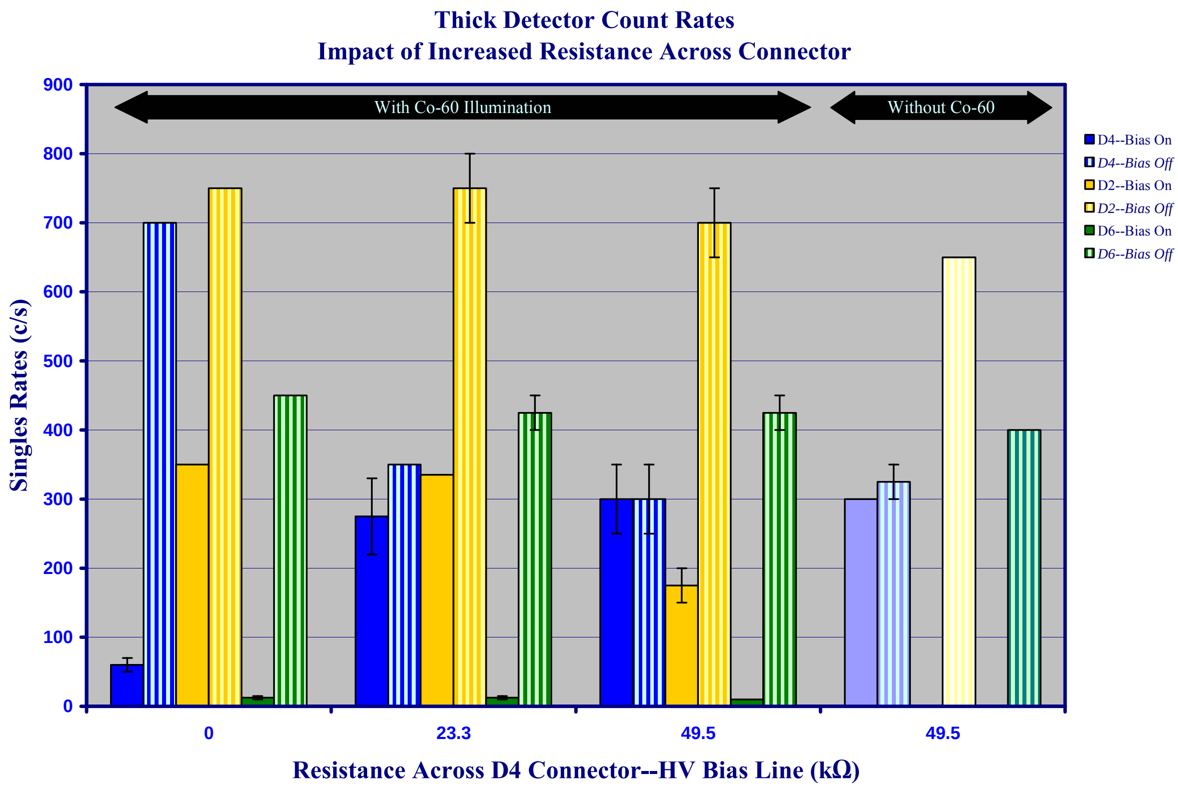


FIGURE 5: Singles rates for 3 thick detectors in various configurations on the EM. The left-most 3 columns were acquired with a Co-60 source on the zenith side of the telescope. There was a variable resistor across the D4 HV bias line connector.

0Ω (with source):
With 0Ω across the connector, singles rates appear nominal (the singles rates are non-zero with the bias on due to the Co-60 source). Rates rise in all 3 detectors when the bias is turned off.

23.3Ω and 49.5Ω (with source):
With resistance across the connector, we see a rise in D4 singles with the bias on, compared to the zero-resistance case.

49.5Ω (without source):
With a resistance across the D4 connector and no source, D2 and D6 behave as expected (i.e. no singles counts with bias on, but elevated singles rates with bias off). On the other hand, D4 singles are very high with the bias on, but with the bias off, they do not increase appreciably.

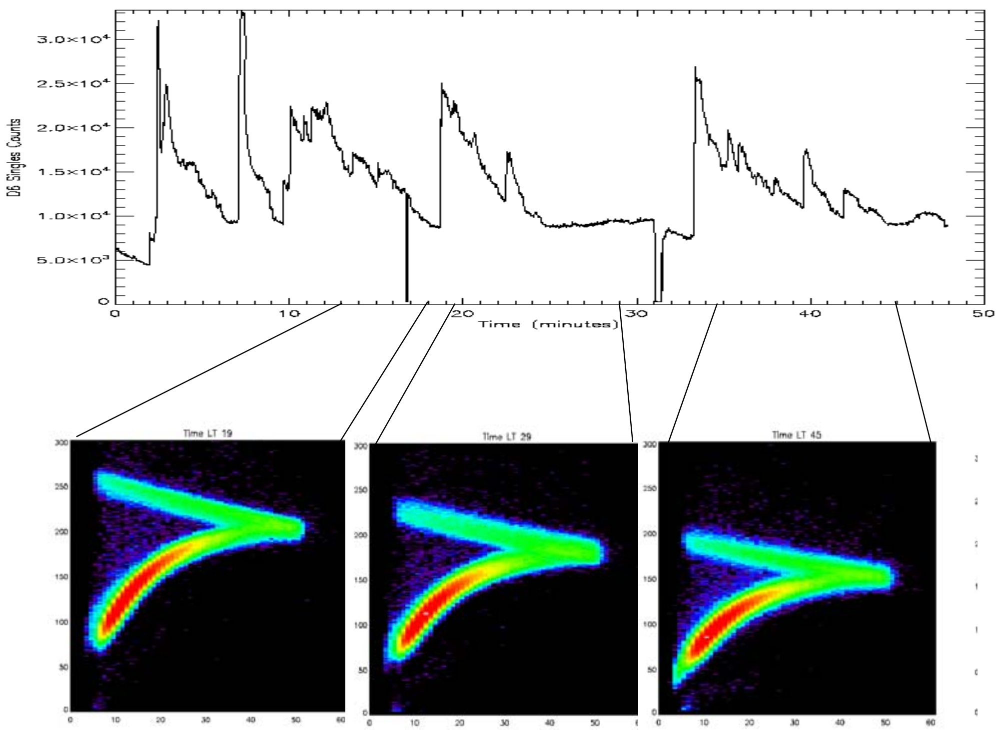


FIGURE 6: Top Frame: D6 singles rate as a function of time. This is indicative of the total beam rate that was being delivered to the instrument. Since the rate drifts down it must be adjusted up about every 10 minutes or so.

Bottom Frames: 2D histograms of D2 pulse-height vs. D1 pulse-height. In all cases the apparent gain of D2 is lower than expected. Each histogram was taken from data only between the indicated times. The apparent gain drifts steadily downward over the course of the run. The rate of the decrease has not been correlated with any other factors.