Chandra Flight Note

FLIGHT NOTE NO.	443
SUBJECT	HRC Use in RADMON Process
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1 Summary

The HRC anticoincidence shield and MCP total event rates can be used to supplement or replace the EPHIN coincidence channel fluxes within the RADMON process. The capabilities of the HRC for radiation sensing are much less than those of EPHIN; the HRC is more sensitive to fluxes of high-energy particles than our current high-energy proton safing channel (P41GM) and does not have sensitivity to our low-energy proton safing channel (P4GM). The use of EPHIN should be maintained as long as practical through the modification of safing thresholds and the selection and/or replacement of the EPHIN channels monitored for instrument safing. The HRC should only be employed in RADMON as part of the active safing system once it contributes capability that is no longer available from the EPHIN.

2 Background

The continuing degradation of the thermal control surfaces used to regulate the EPHIN temperature has led to a concern over the possible loss of the EPHIN for safing the science instruments during solar storms or as a backup in case of radiation-zone location errors or errors in commanding to prepare for radiation-zone entry. The EPHIN instrument uses coincidences in a stack of six detectors (a combination of ion-implanted Si and lithium-drifted Si or Si(Li)) plus a surrounding guard detector (scintillator read by a photomultiplier tube (PMT)) to define the type and energy range of the incident particles. The EIO provides an interface between the EPHIN and the spacecraft and collects data from the EPHIN for inclusion in telemetry. The EIO also takes a subset of the collected data and provides it to the OBC for use within the RADMON process in the OFP; these data are hardware “aliveness” bits, counts in a variety of coincidence channels that correspond to various particle energy ranges, and individual detector counts. The RADMON process uses the “aliveness” bits to monitor the health of the EPHIN and EIO and thirteen coincidence channels to monitor the radiation environment. We currently use three of the thirteen EPHIN coincidence channels within the RADMON process for safing in the event of high radiation; these channels are shown in table 1 along with the coincidence condition among the detectors with the EPHIN that defines the channel. Elevated temperatures are expected to lead to degradation in the performance of the lithium-drifted Si detectors (detectors C, D, and E) by increasing the diffusion of the lithium.

Table 1: Monitored EPHIN Channels

Channel	**Particle**	**Energy Range (MeV)**	**Coincidence Condition**
P4GM	Protons	5.0 - 8.3	A1 $\overline{\mathrm{A4}}$ B0 $\overline{\mathrm{C0}}$ $\overline{\mathrm{D0}}$ $\overline{\mathrm{E0}}$ $\overline{\mathrm{F0}}$ $\overline{\mathrm{G0}}$
P41GM	Protons	41.0 - 53.0	A1 $\overline{\mathrm{A2}}$ B0 C0 D0 E0 $\overline{\mathrm{F0}}$ $\overline{\mathrm{G0}}$
E1300	Electrons	2.64 - 6.18	A0 $\overline{\mathrm{A1}}$ B0 C0 D0 $\overline{\mathrm{E0}}$ $\overline{\mathrm{F0}}$ $\overline{\mathrm{G0}}$

Notes: "An" indicates a threshold level in the A detector; an over-bar indicates "NOT"

In addition, the elevated temperatures lead to increased leakage currents in the detectors which have triggered episodes of reduced HV on the detectors and a resulting period of enhanced diffusion of the lithium. The degradation is expected to manifest itself as additional noise on the detectors which may reach levels that impact the sensitivities in the coincidence channels. The impact of this degradation on the utility of the EPHIN for science instrument safing may be mitigated by changing safing thresholds, by changing the averaging of the samples, or by selecting alternative coincidence channels for active monitoring.

The HRC anticoincidence shield is made of plastic scintillator blocks which surround the HRC detector housing on five sides and is readout by one of two PMTs. The anticoincidence shield and micro-channel plate (MCP) detector total event rates were planned as additional signals to monitor for high radiation but their active use in the RADMON process was dropped during pre-launch software development. Signals are available from both the A-side and B-side HRC electronics, although only one of these sides (currently the A-side) will be meaningful at a time. The OBC has access to these HRC rates and the RADMON process has been patched to replace the EPHIN Helium channel data with the HRC rate data. Table 2 gives the MSIDs of the HRC signals, their descriptions, and the EPHIN He channels to the OBC that they replaced. Additional software patches are required in order to begin to actively monitor the HRC rates for the purpose of safing the science instruments; these patches are to select the HRC rates for use and to set the safing thresholds. If EPHIN were to have a catastrophic failure an additional patch to set the K-constant **KR.EPHIN_On** to **FALSE** would be required to make the RADMON process continue to function without a working EPHIN.

3 HRC Performance

The primary function of the HRC anticoincidence shield is to detect particles that penetrate the MCP detectors so that they might be distinguished from the X-ray events. In order to make effective use of the HRC anticoincidence shield rate as part of the RADMON process a threshold for declaring that we are in a high-radiation environment must be determined. The PMT must have HV applied in order for the rate to be measured and this only happens outside the radiation zone. Data were collected from the anticoincidence shield for all time spent outside the radiation zone

Table 2: HRC Rate MSIDs

MSID	**Description**	**Replaced EPHIN Channel**
2DETART	MCP Total Rate CEA-A	H4GM
2SHLDART	anticoincidence Shield Rate CEA-A	H8GM
2DETBRT	MCP Total Rate CEA-B	H25GM
2SHLDBRT	anticoincidence Shield Rate CEA-B	H41GM

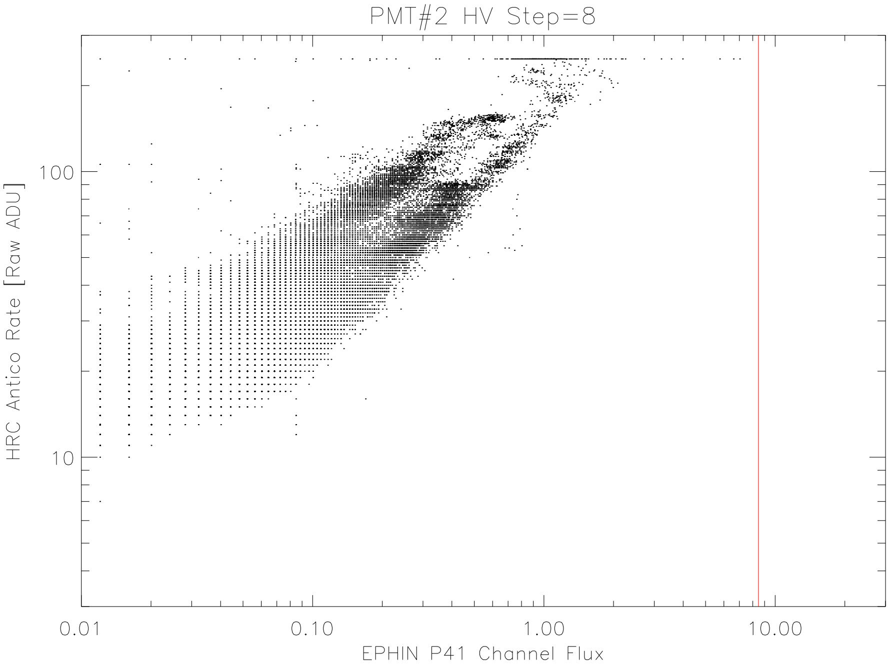

Figure 1: Raw HRC anticoincidence shield rate *vs* EPHIN P41GM channel flux. The vertical red line is the P41GM safing threshold.

for roughly the first year of the mission. After this initial year, nominal operations were modified so that the anticoincidence shield PMT HV was only raised in conjunction with performing HRC observations so as to maximize the operating life of the PMT. As the concern over the possible failure of EPHIN grew, we resumed the collection of data from the HRC anticoincidence shield when outside of the belts but at various reduced HV levels when the HRC was not being used for the observation. Comparisons of the HRC anticoincidence shield rate to the EPHIN channels used for radiation safing provide one means of accessing the utility of the anticoincidence shield in the RADMON process and establishing an appropriate threshold for safing. Figures 1, 2, and 3 are scatter plots comparing the raw (as seen by the OBC) HRC anticoincidence shield rate data, taken at the nominal operational HV step level of 8, to the EPHIN P41GM, P4GM and E1300 channel fluxes, respectively; the red line in each figure is the safing threshold for that channel.

The raw HRC anticoincidence shield rate data corresponds to the upper byte on the number of counts per second observed; it reaches a ceiling at a value of 248, where either a digital-to-analog or analog-to-digital converter limits the maximum value to below the possible maximum of 255. From these scatter plots it is apparent that the anticoincidence shield is a poor match to the P4GM and E1300 fluxes. The anticoincidence shield rate roughly tracks the P41GM flux but with different scaling factors for individual high-flux events. Extrapolating the anticoincidence shield rate trends to higher P41GM flux results in hitting the ceiling value of 248 before reaching the safing flux level. Data collected at lower than nominal PMT HV levels exhibits the same behavior as shown in these plots. The effect of lowered voltage on the scaling between the anticoincidence shield rate and the P41GM flux is smaller than the event to event variations; so, there is no advantage of operating at a reduced HV level. The appropriate safing threshold for the HRC anticoincidence shield rate in the RADMON process must be near the ceiling value so as to minimize the possibility of an

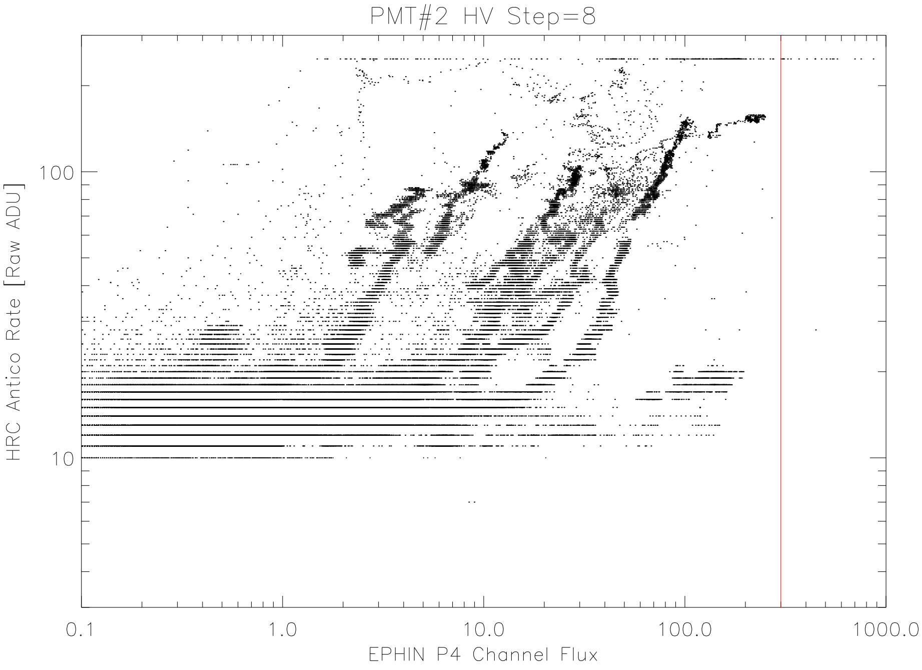

Figure 2: Similar to figure 1 but *vs* EPHIN P4GM channel flux.

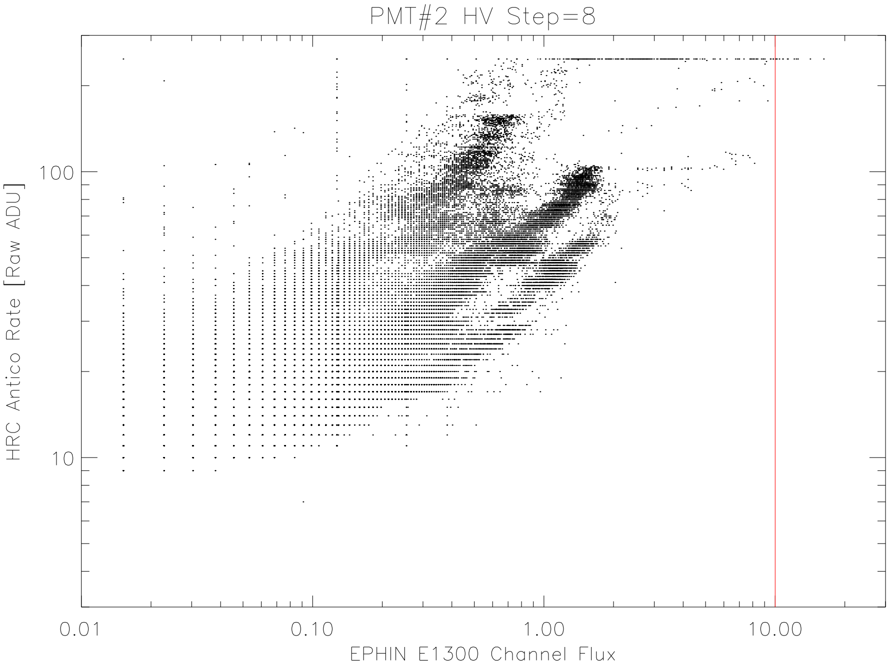

Figure 3: Similar to figure 1 but *vs* EPHIN E1300 channel flux.

Table 3: HRC anticoincidence Shield “Triggers”

Time (UT)	**Description**
1999-11-11 23:46:52	at radzone exit (before institution of pad on AE8 model)
2001-08-16 01:44:27	∼1400 seconds before E1300 trip
2001-12-26 06:14:53	∼870 seconds before E1300,P41GM trip
2002-11-09 23:02:40	∼15170 seconds before P4GM trip
2003-10-26 19:21:05	∼80 seconds before E1300 trip
2005-01-16 08:42:51	∼21660 seconds before P4GM,P41GM,E1300 trip

unnecessary safing trigger. Setting the safing threshold to trigger at a raw HRC anticoincidence shield rate value of 245 would provide some margin to monitor the potential for changes in the ceiling value.

A concern with using the HRC anticoincidence shield rate for safing from high radiation fluxes is that even with the threshold set as high as is practical there might be too many unnecessary safing triggers. The RADMON logic requires ten consecutive samples of the monitored channel (one sample every 65.6 seconds) to be above the threshold before declaring a high-radiation environment. Using data collected when the anticoincidence shield PMT HV was at its nominal step of 8, there were six instances when we would have expected a safing trigger from the HRC anticoincidence shield with the threshold at 245; these are given in table 3. The first of these events would not have happened given our current scheduling of radiation zone times but it provides a demonstration that the HRC anticoincidence shield should protect against an un-safed radiation zone entry. The remaining events all occurred prior to RADMON triggers of the science instrument safing sequence, two of them by more than a few hours. An examination of the anticoincidence shield data, similar to the one above for HV step 8, for data taken with the PMT at reduced HV steps of 5, 6, and 7 returns no times when the RADMON process would have triggered a safing action. There were several other safing events triggered by RADMON during the time range spanned by these data. Table 4 lists all of the RADMON triggers that occurred while the HRC anticoincidence shield was active at any of the HV step levels used for data collection. Listed in the table are: the HV step for the anticoincidence shield PMT, whether the anticoincidence shield rate would have caused RADMON to trigger a safing action prior to the RADMON trigger, and the EPHIN channel that caused the RADMON trigger. Since the HV to the anticoincidence shield PMT is turned off as part of the science instrument safing sequence, we have no information on how long until, or even whether, the anticoincidence shield rate would have reached the safing threshold for those events where it did not occur prior to the RADMON trigger. For many of the the events in table 4 the RADMON triggers were caused by electron contamination of the P4GM channel near the entry to the radiation zone and a few of these would not currently trigger the RADMON process as they did not exceeded the threshold for ten consecutive samples.

4 Strategy for HRC Use in RADMON

The HRC anticoincidence shield rate is a poor replacement for the capability we have with the EPHIN detector, as it provides no measure of the low-energy protons that we have with the P4GM channel. Even as a backup to the EPHIN P41GM channel it appears less than optimal with the possibility for unnecessary safing triggers and the resulting loss of science time. Given these limitations of the HRC anticoincidence shield rate, the use of EPHIN should be maintained as

Table 4: RADMON triggers with HRC anticoincidence shield on

RADMON Event	HV Step	Antico Shield "Trigger"	Cause
08−Jun−00	8		P4GM
16−Aug−01	8	Y	E1300
26−Dec−01	8	Y	E1300
10−Nov−02	8	Y	P4GM
17−Apr−03	7		P4GM (electron−contaminated) *
30−Apr−03	7		E1300, P4GM (electron−contaminated)
08−May−03	7		P4GM *
22−Jun−03	7		P4GM (electron−contaminated) *
01−Aug−03	6		P4GM (electron−contaminated) *
26−Oct−03	8	Y	E1300
02−Dec−03	8		P4GM
29−Jun−04	5		P4GM (electron−contaminated)
26−Jul−04	5		E1300
28−Jul−04	5		E1300
13−Sep−04	8		P4GM, E1300
16−Jan−05	8	Y	P4GM, P41GM, E1300
06−Apr−05	8		P4GM (electron−contaminated)
14−May−05	8		P4GM

* Fewer than ten samples

long as practical through the modification of safing thresholds, sample averaging, and the selection and/or replacement of the EPHIN channels monitored for instrument safing. **The HRC should only be employed in RADMON as part of the active safing system once it contributes capability that is no longer available from the EPHIN.** Obviously, a catastrophic failure of EPHIN will require that we begin to use the HRC anticoincidence shield rates as our on-board radiation monitor. It is expected that the HRC rates would likely be required to replace the high-energy channels that EPHIN currently supplies, maintaining at least two channels monitored for safing (EPHIN P4GM for low energy and HRC for high energy). An overall flow of the decisions for modifying RADMON to account for EPHIN degradation is given in figure 4.

The EPHIN data are being routinely monitored for changes that will affect its performance in detecting high radiation. One specific concern are the observed episodes of voltage drop on the +27V supply output that are initiated by high temperatures. During these intervals the drop in the +27V output causes the output of the high-voltage supplies that bias the EPHIN detectors and that powers the EPHIN detector-G PMT to drop. The drop of the HV on the Si(Li) detectors leads to an increase in diffusion of the lithium which will ultimately lead to a permanent increase in their leakage currents. The drop of the HV on the detector-G PMT results in the loss of some of the anticoincidences it would normally supply, increasing the apparent flux in the EPHIN channels used for safing (most notably the E1300 channel). The net result of the HV supply output drop is that the EPHIN safing channels of E1300, P4GM and P41GM are more sensitive to radiation (i.e. more likely to generate an unwanted trip); they do not appear to be less sensitive to radiation during the current-limit episodes. Nevertheless, the EPHIN degradation is most likely to increase likelihood of +27V current-limit episodes and we must continue to closely monitor these to detect departures from the previously observed behavior and plan the mission such that the spacecraft

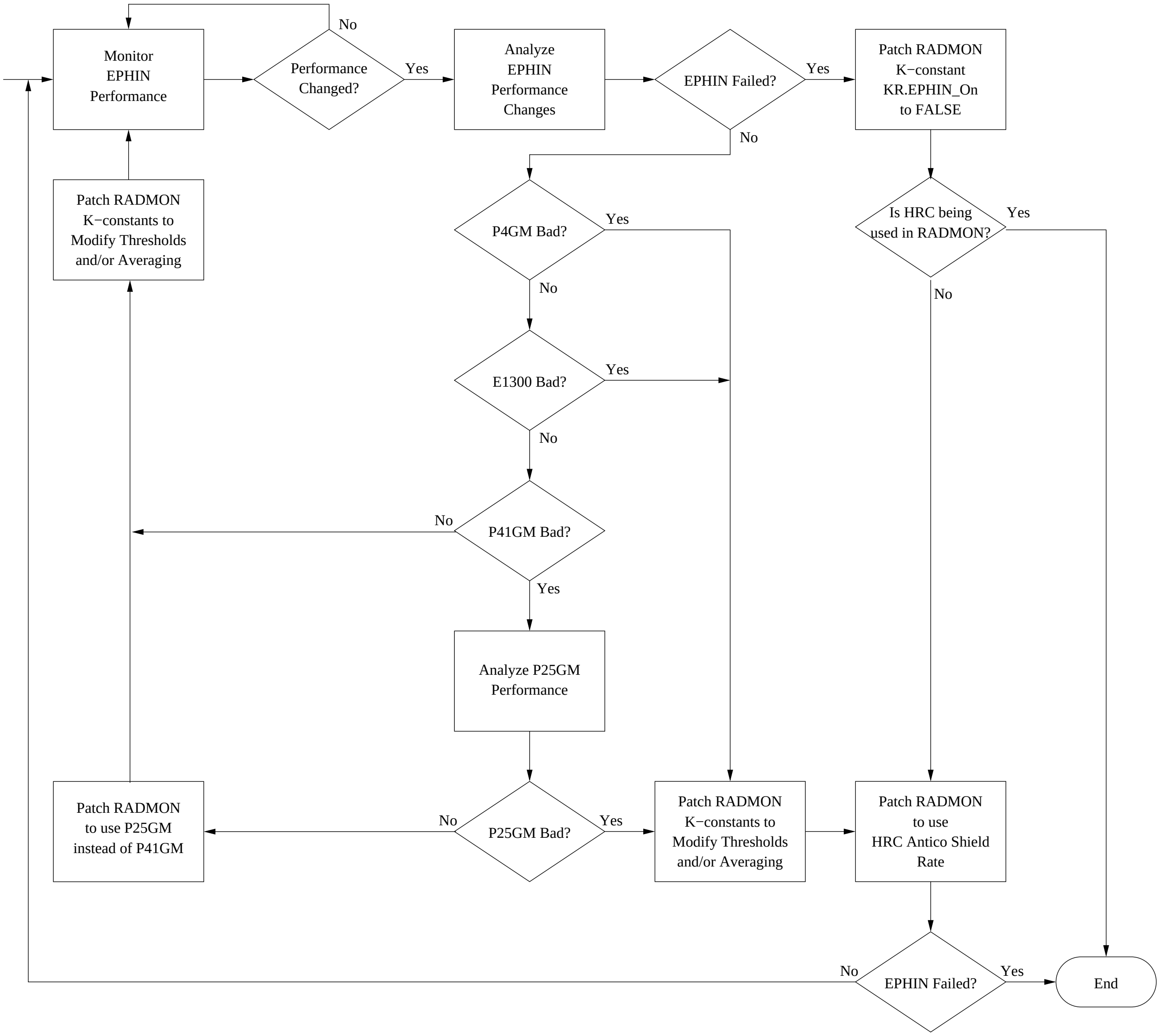

Figure 4: Logic flow for the decision on modifications to RADMON to account for EPHIN degradation.

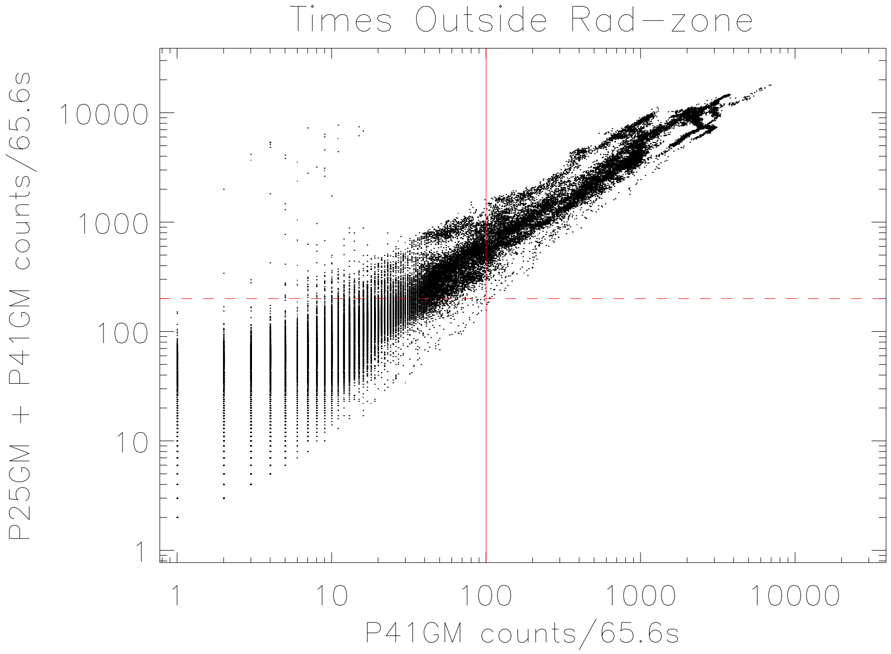

Figure 5: Sum of P25GM and P41GM counts as a function of P41GM counts. The vertical red line is the trigger threshold used for radiation safing. The horizontal dashed red line is a possible threshold on the P25GM channel after detector E has been logically switched off from contributing to the coincidence logic.

attitude profile limits the instances and duration of current-limited behavior of the +27V supply.

The increase in EPHIN detector leakage currents may eventually lead to increased noise in the detectors. If the noise in a detector gets too high ($> 10^6$/minute) it will impact the coincidence rates by producing a high dead-time and should be logically switched off in the coincidence logic. Currently detector E is noisy but not at a rate that is of concern; however, it is considered to be the most-likely detector to first encounter degradation induced performance losses. Logically switching off detector E will eliminate E3000, P41,and H41 events, by removing the coincidences that are a part of their definition; as a result we would lose the P41GM channel from safing. The events that had formerly been counted as P41GM events would appear in the P25GM channel; in principle we could switch to using P25GM as a replacement for P41GM for safing purposes. Figure 5 shows a comparison of the sum of the P25GM and P41GM counts to the P41GM counts for all the EPHIN data collected outside the radiation zones for the mission up to December 2004. Using a safing threshold of 200 counts/65.6 s on this expanded P25GM channel would have caught all of the past P41GM induced safing triggers, caught some of the E1300 and P4GM induced safing triggers early, and caused only one unnecessary safing trigger. As with the P25GM channel, the E1300 channel will cover a broader energy band by having the E3000 events contributing. However, this additional contribution does not add significantly to the the counts in E1300 channel; the E1300 threshold will not need to be raised to avoid unwanted RADMON triggers.

If rather than detector E, one of the other Si(Li) detectors (C or D) had to be logically switched off even more coincidence channels would be affected and recovery of the capabilities of the P41GM and E1300 channels would not be possible by switching to another coincidence channel. In this case, the HRC anticoincidence shield rate would have to be used within the RADMON process to provide a high-energy channel for safing. The EPHIN P4GM channel would still be usable provided the A and B detectors are still functioning in the coincidence logic, although the safing threshold may require a change if the C detector has been logically switched off.