# KOPIO Technical Note 127
# A Look at Singles Rates in KOPIO

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## 1 Introduction

It is interesting to look at singles rates in KOPIO subdetectors for several reasons, among which are:

- Issues of veto blindness
- Specification of FADC speed in WFD's
- Possible multiplexing of readout electronics in low-rate regions to reduce the cost.
- Estimation of maximum allowable L1 trigger rate
- Estimation of DAQ data rates

This note describes some rate studies using the KOPIO GEANT Monte Carlo. It should be understood that it is just a snapshot, using whatever we have in the current Monte Carlo. The charged vetoes were excluded in this study. Catcher rates have been studied in detail elsewhere [1] and those references should be consulted for the definitive word on the Catcher.

## 2 Technical Details

Version 7.0 of the GEANT Monte Carlo was used. A couple of bug fixes were backported and put in by hand into my local copy of the source code; these were the RNMAXF fix in V7.2 and the $K_L$ decay range bug fix in V7.4. The main reason for not using the most up-to-date version of the Monte Carlo is that I use a specially hacked version that puts spatial information of the hits into the output ntuple; this information is needed to properly group the detector hits into the segmentation used for readout.

The output ntuple from the Monte Carlo contains a separate entry for every hit in each "unit" of active material; thus for example in the Shashlyk calorimeter, each of the 300 layers of scintillator in a single Shashlyk module can have a hit (time, energy and space point) associated with it. This actually turns out to be an advantage because it allows the user to group the hits into a different readout configuration.[1] The following spatial configuration of readout channels was used in this study:

- Barrel Veto. The Monte Carlo still contains the old "log" geometry, but the hits are regrouped into the segmentation expected from the new Shashlyk modules. The barrel was divided into 20 segments in Z and 54 segments in $r\phi$.
- Preradiator. The 9 scintillator planes per module (X,Y,U) were regrouped into X and Y planes, with 4 (5) planes of vertical[2] (horizontal) "planks". I retained the configuration of 10 planks per quadrant where each plank is 20cm wide. Hits were combined in each module along Z for each X (Y) plank.
- Upstream PV wall. The wall was divided into a 32 by 6 array in the YZ plane, i.e. the wall is 6 logs deep in Z and 32 logs high.
- Calorimeter. The calorimeter was subdivided into a 52 by 52 array in the XY plane. Hits were combined along Z for readout.
- Downstream magnet veto. The logs are oriented horizontally above and below the beam and vertically to the left and right sides of the beam. There are 20 segments in Z.
- Downstream vertical veto. The logs are oriented horizontally above and below the beam in 6 modules at 3 Z locations. Each module is subdivided into a 4 by 4 array for readout.
- Downstream horizontal veto. The logs are oriented vertically to the left and right sides of the beam in 12 modules at 6 Z locations. Each module is subdivided into a 2 by 2 array for readout.
- Catcher. No modifications. However, this version of the catcher had modules whose transverse dimensions were $20cm \times 20cm$. There were 25 layers in Z with 20 (21) modules per odd (even) layer.

The segmentation of the downstream vetoes is not really well defined at this point. The numbers above are consistent with those shown at the recent KOPIO LOG review.

The hits were combined spatially and also in time. If two hits were within 10ns of each other, they were combined into one hit. One other technical detail is that the file sensitive.detector.info was modified so that the output ntuple contained only one energy/time entry for each hit in a sensitive volume; the default settings would produce, for example, two entries for a detector element that was viewed by phototubes on both ends.

The number of $K_L$ per microbunch after the spoiler was 3.57 and the number of neutrons per microbunch from the production target into the beam acceptance was set

[1] Steve Kettell pointed out a potential loophole in this strategy. Taking the barrel veto as an example, hits within one piece of scintillator in a log are combined inside GEANT if they are close in time. Only the combined hit is put into the output ntuple. Thus there is no opportunity to separate them into different output channels by changing the Z segmentation at the ntuple level. The result is a possible underestimate of the rates.

[2] "Vertical" means that the long axis of the plank runs in the vertical direction.

to 600. The neutron halo is generated by GEANT by propagating the neutrons from the production target.[3]

## 3 Rates in Photon Veto Counters

The average rates per counter in the various subsystems are summarized in Tables 1 and 2 where the latter show the results when no neutrons are produced at the production target. The rates in the downstream vetoes are alarmingly high.

| | | Rates per counter (kHz) | | | | |
|---|---|---|---|---|---|---|
| | | Energy Threshold (MeV) | | | | |
| Subdetector | No. elements | "0" | 0.5 | 1.0 | 3.0 | 5.0 |
| PR scint | 640 | 1039 | 550 | 547 | 458 | 392 |
| Barrel Veto | 1080 | 83 | 56 | 47 | 34 | 27 |
| Magnet Veto | 80 | 2113 | 1508 | 1293 | 964 | 828 |
| DS Horiz Veto | 48 | 1318 | 694 | 444 | 166 | 107 |
| DS Vert Veto | 96 | 3660 | 2325 | 1644 | 818 | 611 |
| Calorimeter | 2704 | 97 | 55 | 44 | 27 | 21 |
| Catcher | 512 | 217 | 217 | 191 | 156 | 123 |
| US PV Wall | 192 | 384 | 270 | 228 | 164 | 136 |

Table 1: Singles rates per counter as a function of energy threshold. Neutrons are turned on. The threshold of "0" means no threshold was applied on the GEANT hits; the actual threshold in this case is believed to be a few keV. The effect of the photon flash on the catcher is not simulated; see [1] for the most up-to-date and detailed rate studies on the catcher.

Plots of the number of hits (above 0.5 MeV) per subsystem per microbunch are shown in Figure 1; these give some idea of the type of fluctuations from microbunch to microbunch. The mean of each of these plots was multiplied by 25 MHz and divided by the number of channels to derive the numbers in the 0.5 MeV column in Table 1. Note that the effect of the photon flash is not simulated; the rate in the catcher is expected to be around 3 MHz per counter [2, 1].

The source of the rates (for hits above 0.5 MeV) by particle type is shown for each subsystem in Figure 2. The translation from GEANT particle ID to particle name is shown in Table 3. The plots are normalized to unit area so for each subsystem, one can take the vertical height for each particle type and multiply by the rate in Table 1 to get the average rate in that subsystem due to that particle. It is interesting to note the negligible contribution (at least in GEANT simulation) from neutrons in the preradiator, calorimeter, barrel veto and upstream wall. The subdetectors that have a large effect from neutrons are the downstream vetoes (vertical and horizontal) and (obviously) the catcher.

Figure 3 shows the number of hit modules per track in each of the subsystems, summed over all track types. Clearly this number is particle dependent; these plots just give some average sense of what is going on. In the downstream systems, although not shown here,

[3] I have no clue how realistic this is.

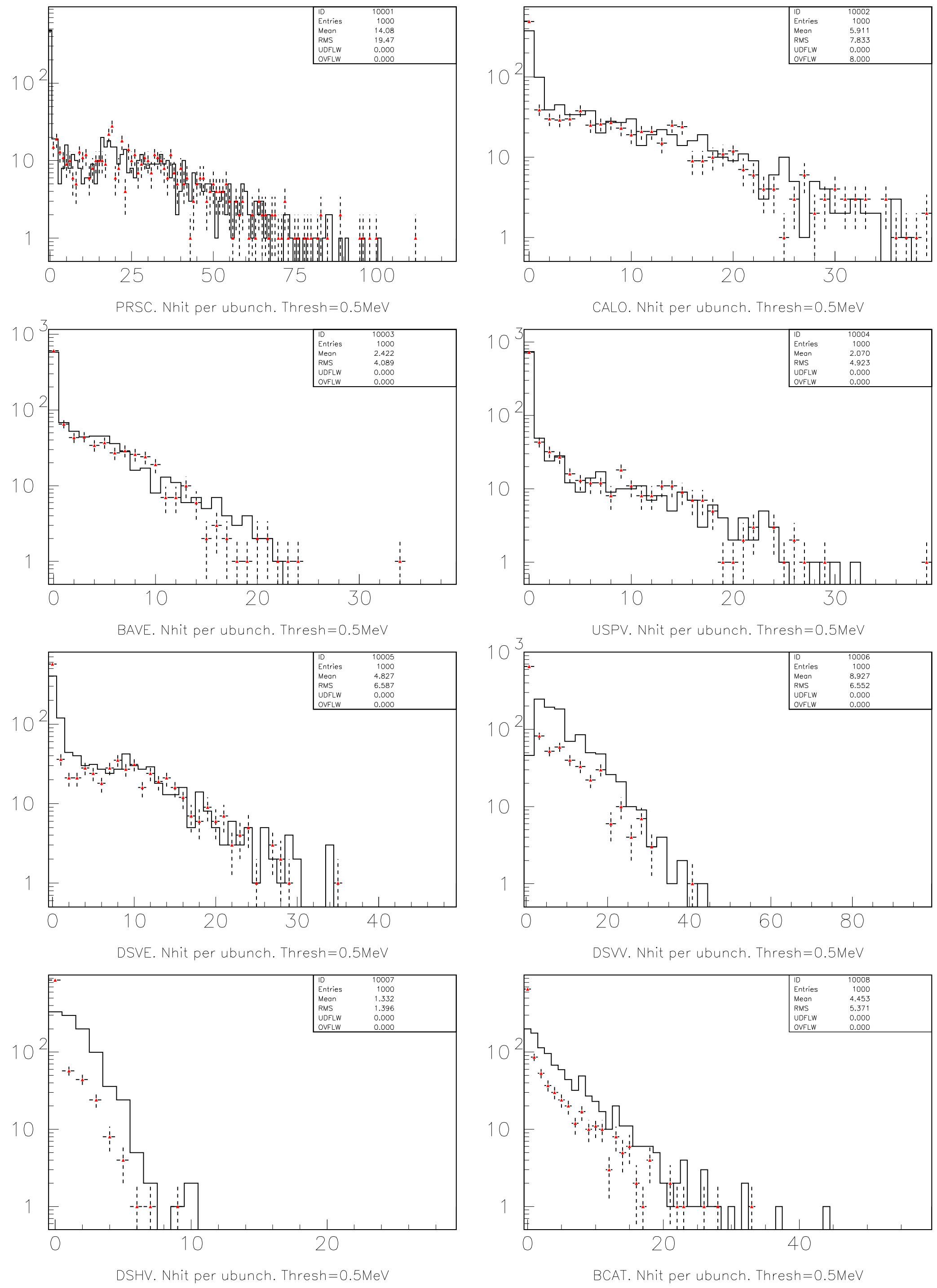


Figure 1: Number of hits (above 0.5 MeV) per microbunch for each subsystem. Histogram: neutrons on. Red triangles: neutrons off.

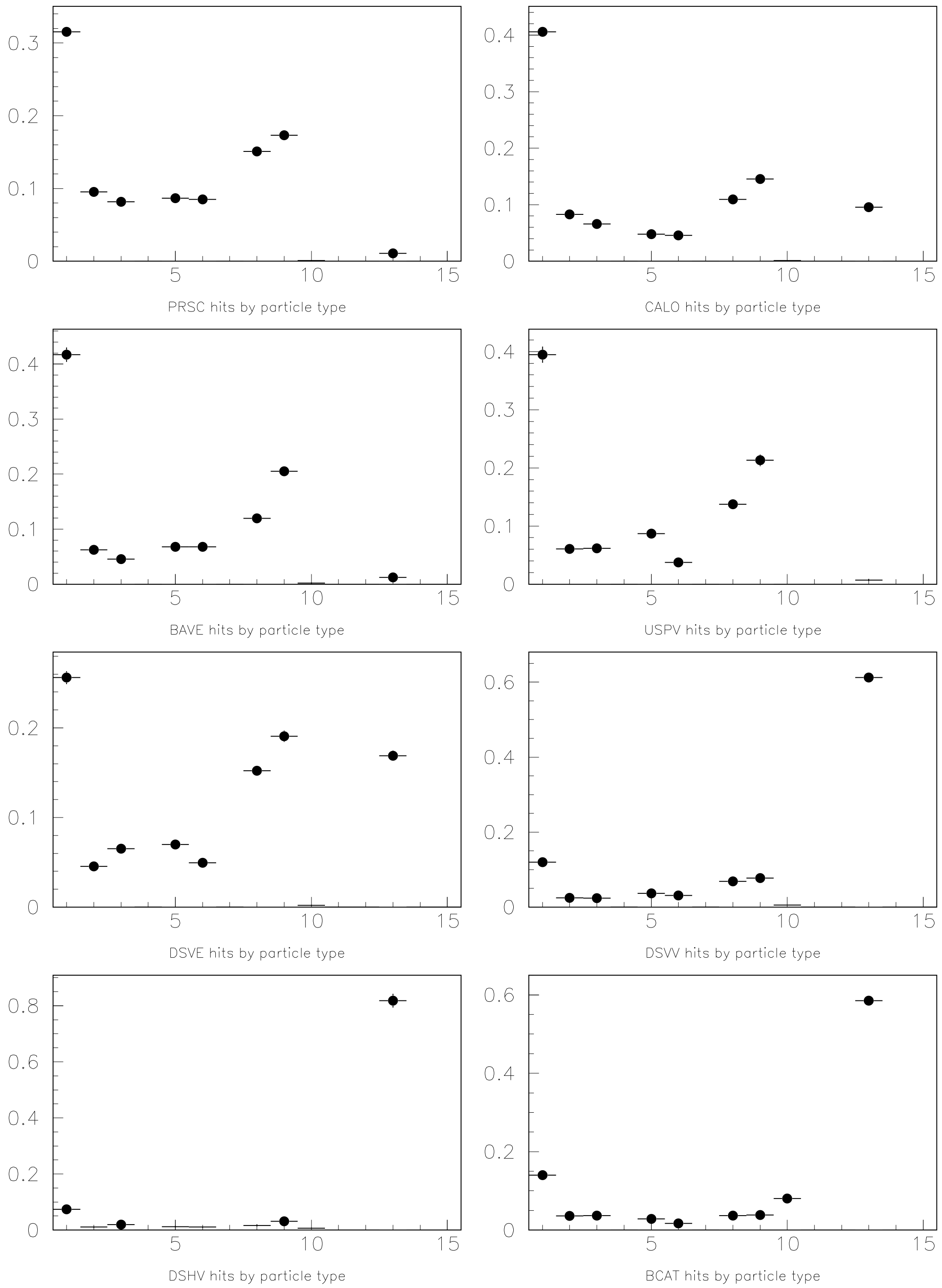


Figure 2: ID of the particle that produced hits in modules in each of the subsystems. An entry is made for each hit in a module in a subsystem. The histograms are normalized to unit area. Only hits above 0.5 MeV are counted. The ID numbers are described in Table 3, but briefly 1 is $\gamma$, 13 is $n$ and the rest are charged particles ($e, \mu, \pi$ from left to right).

| Rates per counter (kHz) | | | | | |
|---|---|---|---|---|---|
| | Energy Threshold (MeV) | | | | |
| Subdetector | "0" | 0.5 | 1.0 | 3.0 | 5.0 |
| PR scint | 1089 | 571 | 561 | 467 | 394 |
| Barrel Veto | 79 | 53 | 44 | 31 | 25 |
| Magnet Veto | 1735 | 1286 | 1137 | 887 | 761 |
| DS Horiz Veto | 214 | 152 | 129 | 90 | 73 |
| DS Vert Veto | 1186 | 1066 | 805 | 592 | 502 |
| Calorimeter | 85 | 50 | 40 | 25 | 20 |
| Catcher | 87 | 87 | 79 | 64 | 49 |
| US PV Wall | 387 | 278 | 236 | 173 | 145 |

Table 2: Singles rates per counter as a function of energy threshold. Neutrons are turned off. The threshold of "0" means no threshold was applied on the GEANT hits; the actual threshold in this case is believed to be a few keV. The effect of the photon flash on the catcher is not simulated; see [1] for the most up-to-date and detailed rate studies on the catcher.

| ID | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Particle | $\gamma$ | $e^+$ | $e^-$ | $\nu$ | $\mu^+$ | $\mu^-$ | $\pi^0$ | $\pi^+$ | $\pi^-$ | $K_L$ | $K^+$ | $K^-$ | $n$ | $p$ | $\overline{p}$ |

Table 3: Translation table for GEANT particle ID number for Figure 2.

neutrons typically hit only one module; thus increasing the segmentation would be effective in reducing the rates. One can also get a sense for the average number of tracks hitting a subdetector per microbunch by taking the mean of these histograms and dividing by the number of microbunches (1000).

Figures 4 through 12 show the rates in a single counter (with and without neutrons) for the various subsystems as a function of counter location; a threshold of 0.5 MeV is applied in all cases. It is worth noting the enhancement in the rate in the downstream vertical veto at the far downstream end (10 MHz per counter at 0.5 MeV threshold!). This appears to be due to neutron backsplash from the catcher.

## 4 Preradiator chamber rates

The rates per wire on the preradiator anodes are shown in Figure 13. The hottest horizontal wire (averaged at the TDC level, or 24 wires) has a rate of about 44 kHz. This differs from the 30 kHz quoted in an earlier study [3] because previously the rates were averaged at the anode card level (96 wires). However, for studies of the maximum L1 trigger rate sustainable by the preradiator front-end electronics, it is the average rate at the TDC level which is relevant.

The number of hits per microbunch for the hottest TDC for the horizontal wires is shown in Figure 14; this gives some idea of the fluctuations from microbunch to microbunch. The average rate per wire is obtained by taking the mean of this plot, multi-

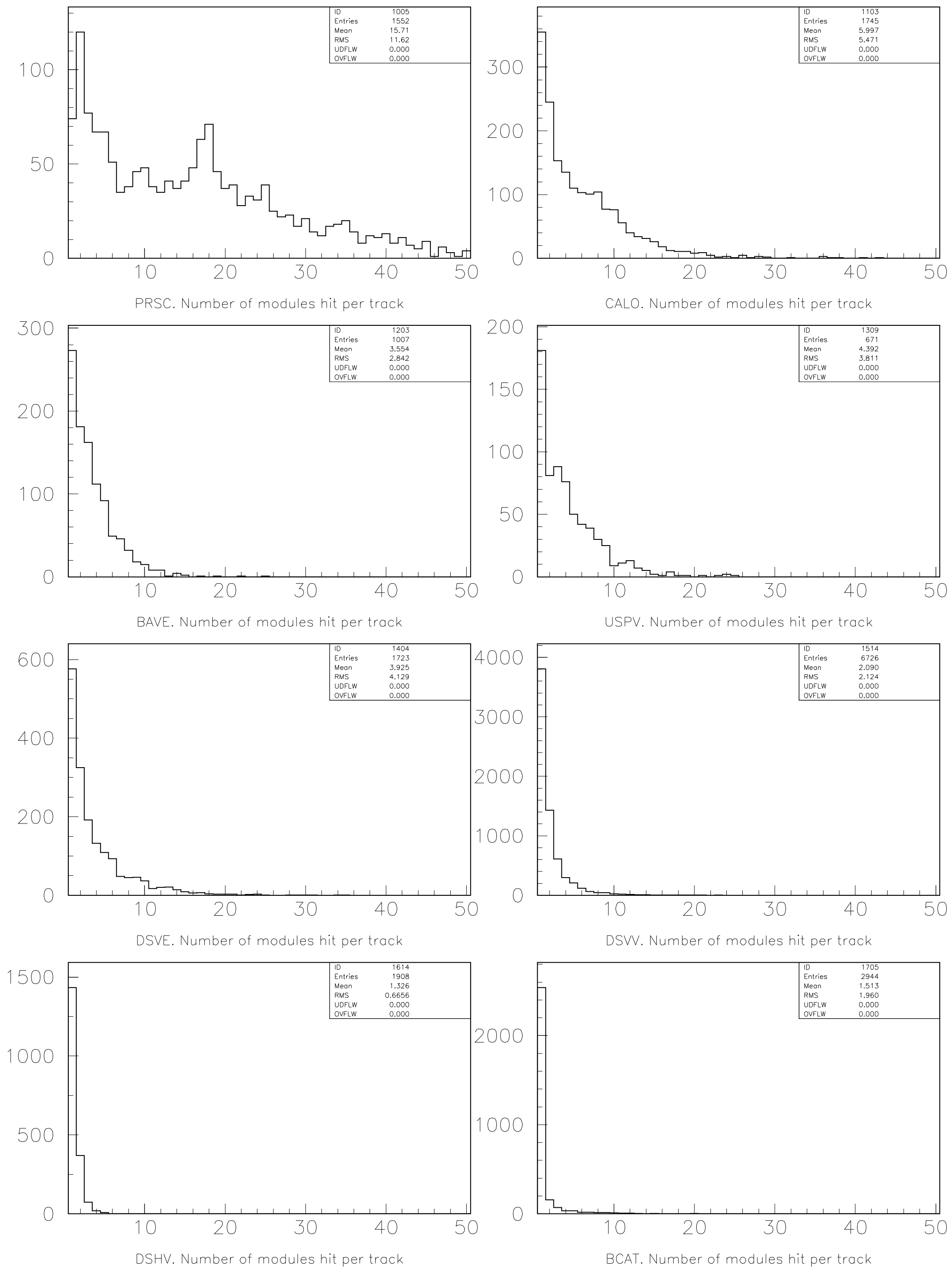


Figure 3: Number of hit modules per track, summed over all track types.

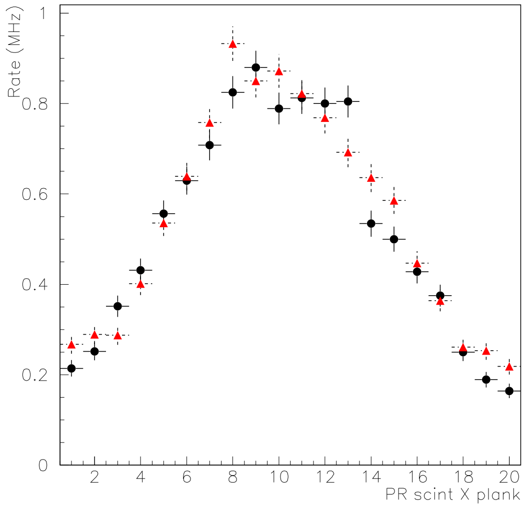


Figure 4: Preradiator scintillator singles rate (MHz) as a function of location in X. These are the planks whose long axis run vertically. An energy threshold of 0.5 MeV is applied. Black dots: neutrons on, red triangles: neutrons off. The rates are approximately independent of Z.

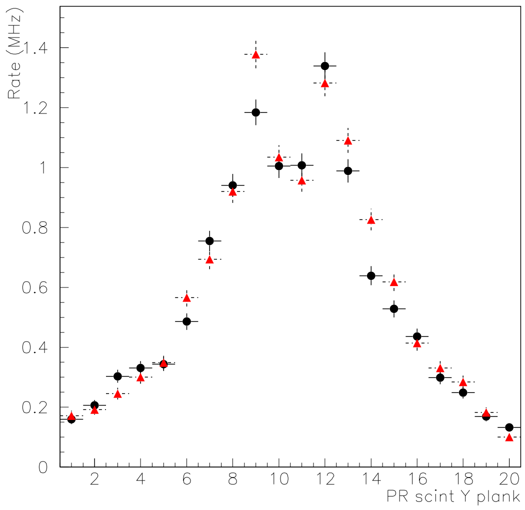


Figure 5: Preradiator scintillator singles rate (MHz) as a function of location in Y. These are the planks whose long axis run horizontally. An energy threshold of 0.5 MeV is applied. Black dots: neutrons on, red triangles: neutrons off. The rates are approximately independent of Z.

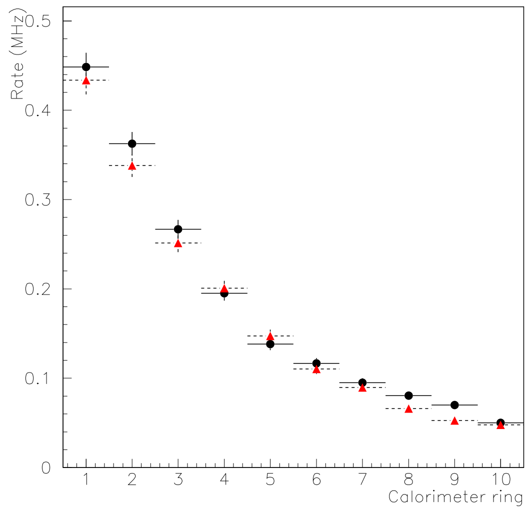


Figure 6: Calorimeter singles rate (MHz) as a function of “ring” number. The “rings” are actually rectangles with an aspect ratio corresponding to the beam hole. The rings are concentric about the center of the beam with a width of one Shashlyk module. An energy threshold of 0.5 MeV is applied. Black dots: neutrons on, red triangles: neutrons off.

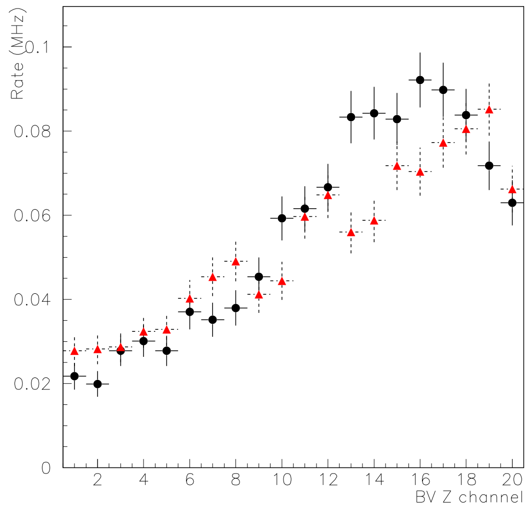


Figure 7: Barrel Veto singles rate (MHz) as a function of location in Z. An energy threshold of 0.5 MeV is applied. Black dots: neutrons on, red triangles: neutrons off. The rates are approximately independent of $r\phi$.

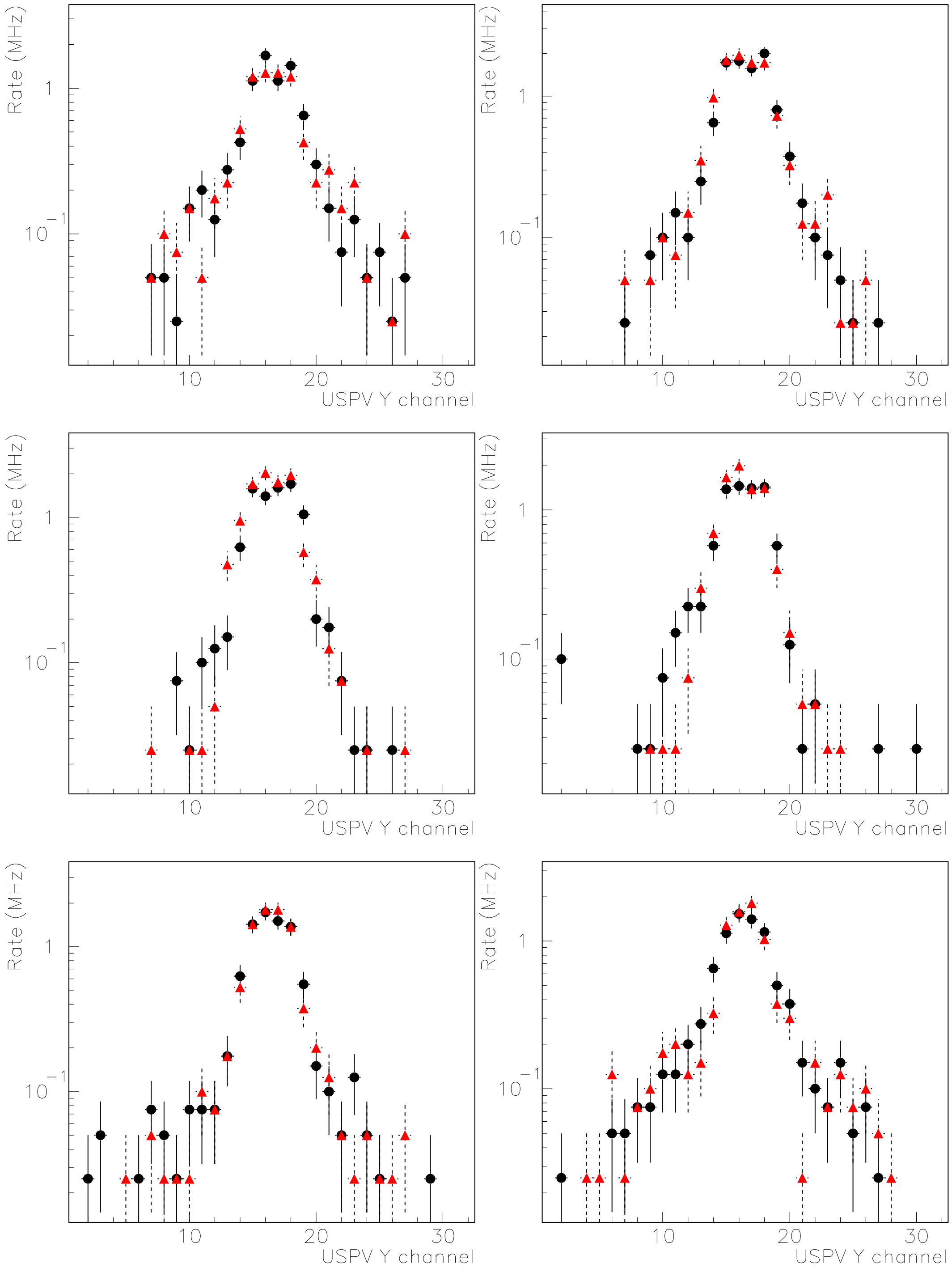


Figure 8: Upstream Wall singles rate (MHz) as a function of location in Y. Each plot is for a different location in Z; the top left is for the upstream end and the bottom right is the downstream end. An energy threshold of 0.5 MeV is applied. Black dots: neutrons on, red triangles: neutrons off.

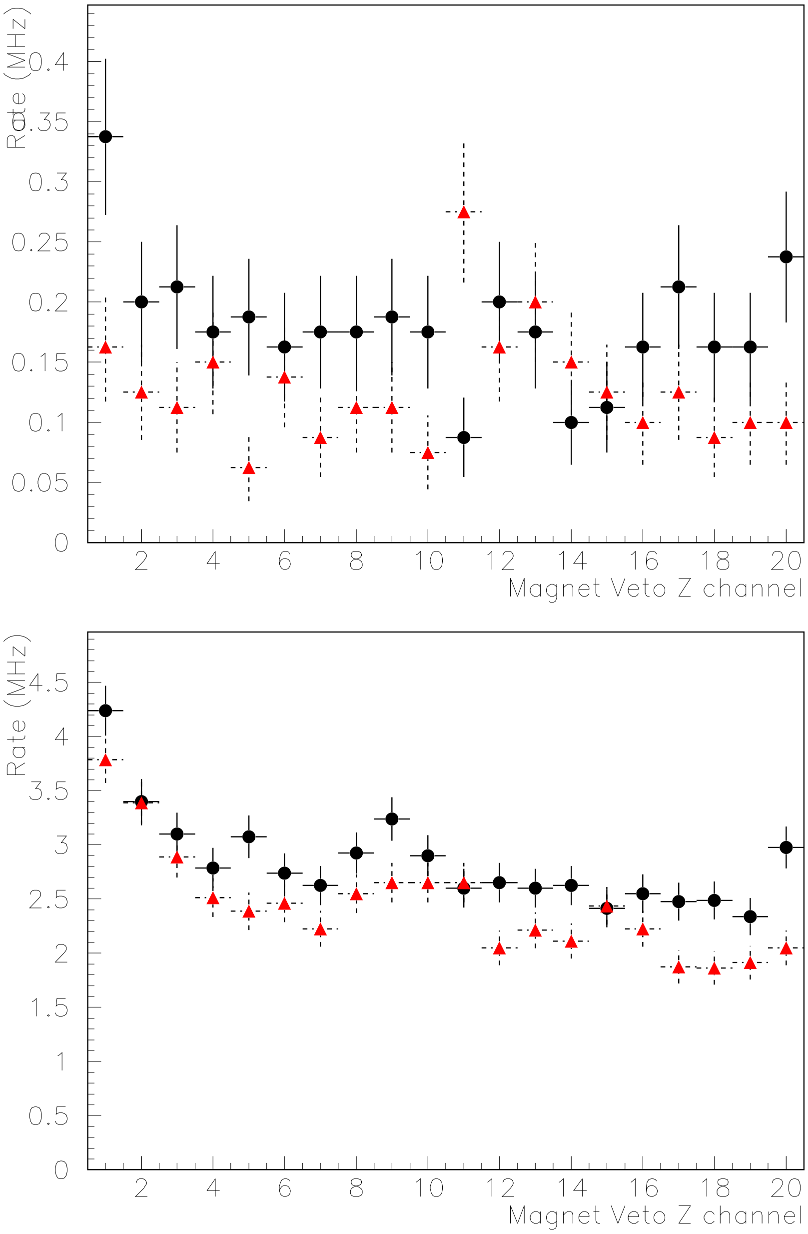


Figure 9: Downstream Magnet Veto singles rate (MHz) as a function of location in Z. The top plot is for the logs to the left and right of the beam, and the bottom plot is for the logs above and below the beam. An energy threshold of 0.5 MeV is applied. Black dots: neutrons on, red triangles: neutrons off.

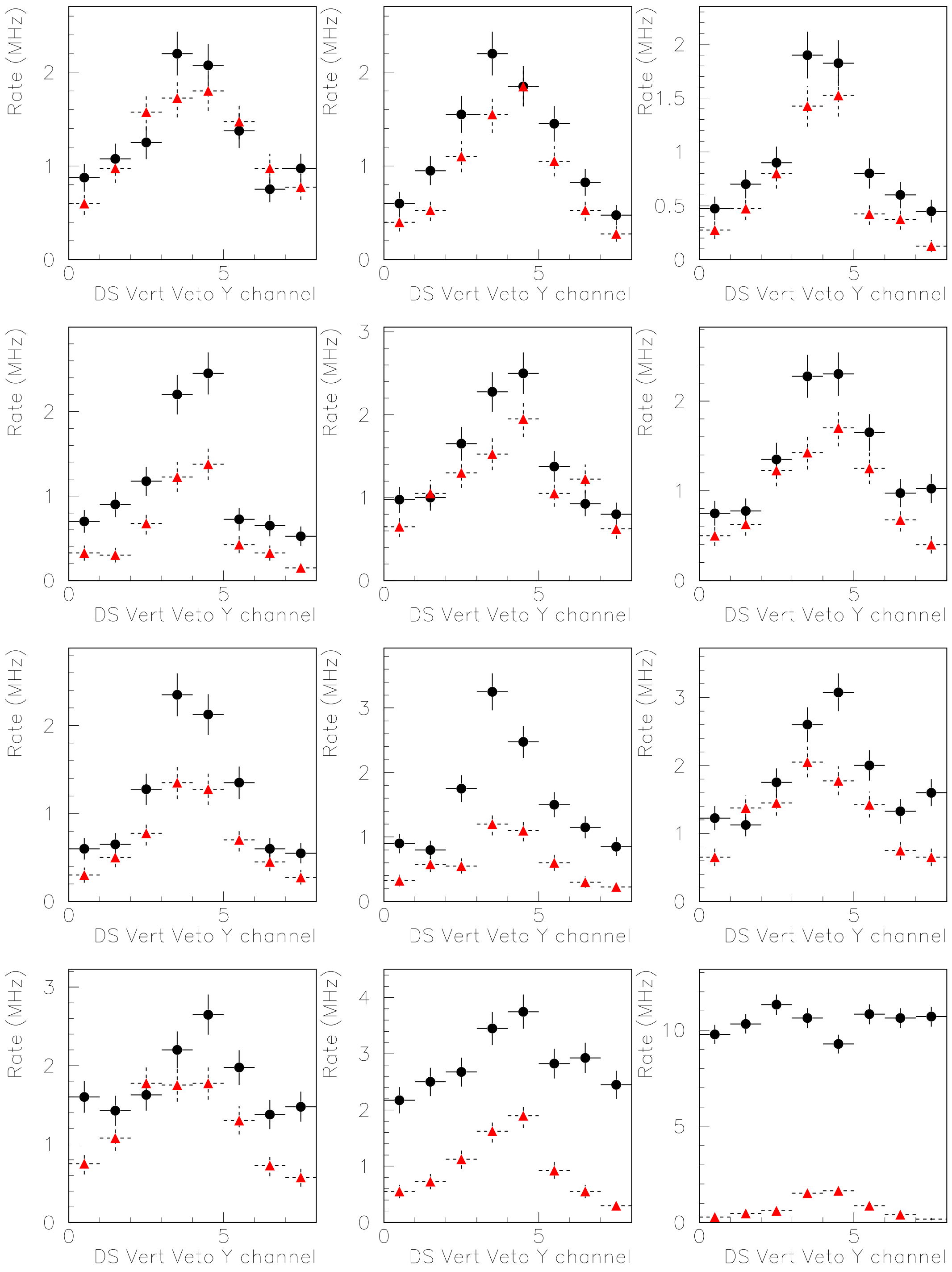


Figure 10: Downstream Vertical Veto singles rate (MHz) as a function of location in Y. Each plot is for a different location in Z; the top left is for the upstream end and the bottom right is the downstream end. An energy threshold of 0.5 MeV is applied. Black dots: neutrons on, red triangles: neutrons off.

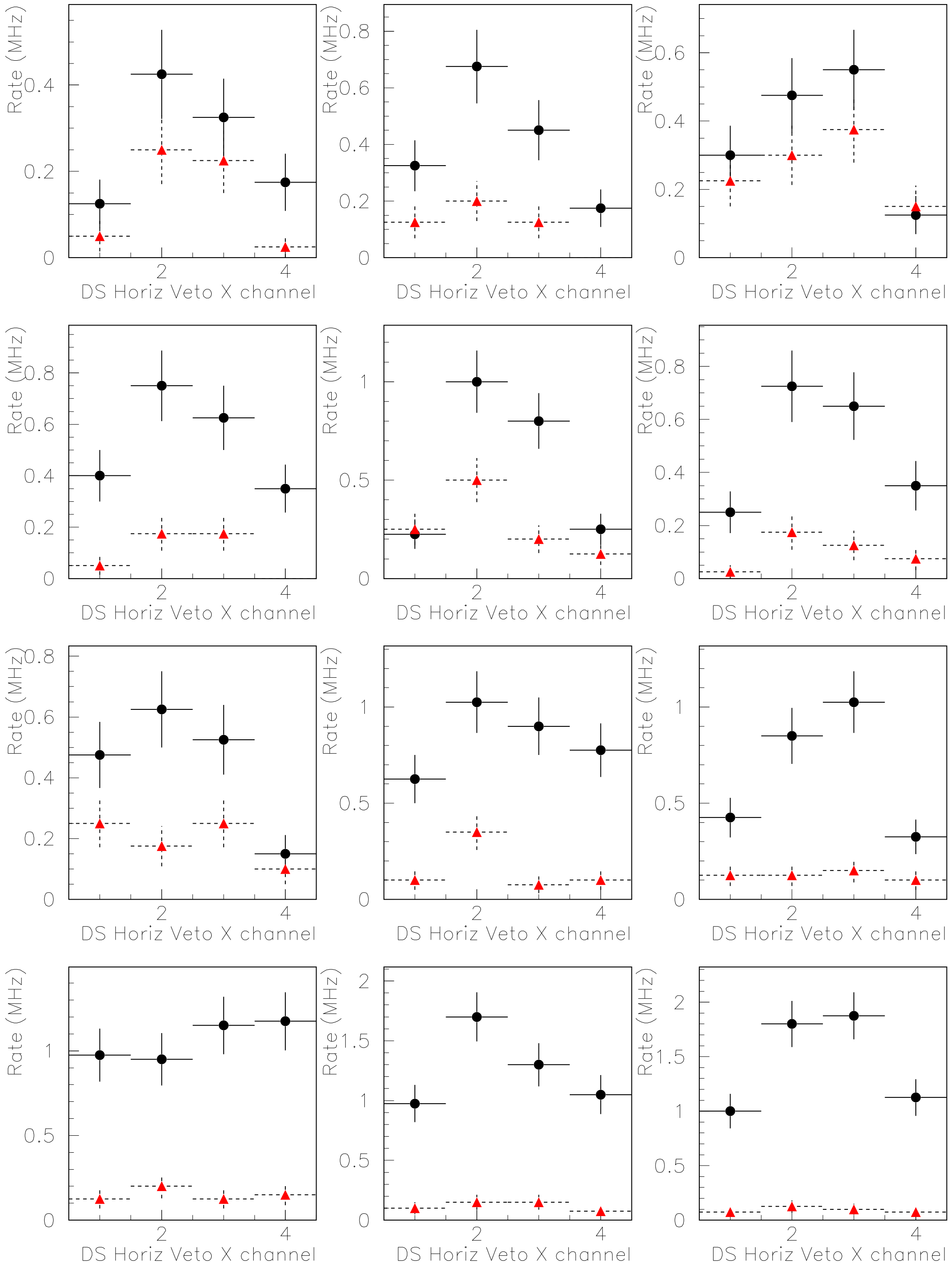


Figure 11: Downstream Horizontal Veto singles rate (MHz) as a function of location in X. Each plot is for a different location in Z; the top left is for the upstream end and the bottom right is the downstream end. An energy threshold of 0.5 MeV is applied. Black dots: neutrons on, red triangles: neutrons off.

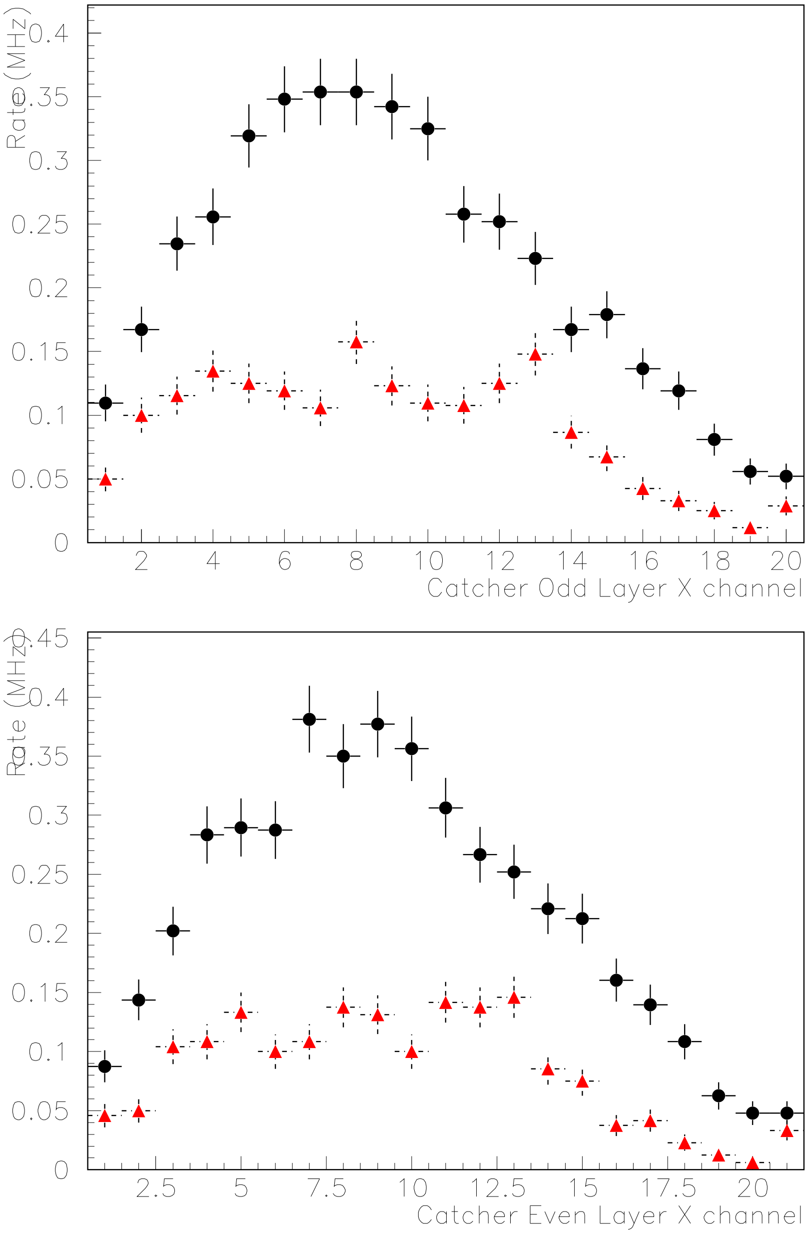


Figure 12: Catcher singles rate (MHz) as a function of location in X. The top plot is for the odd layers (in Z) which have 20 modules in X. The bottom plot is for the even layers which have 21 modules. An energy threshold of 0.5 MeV is applied. Black dots: neutrons on, red triangles: neutrons off. The effect of the photon flash is not simulated.

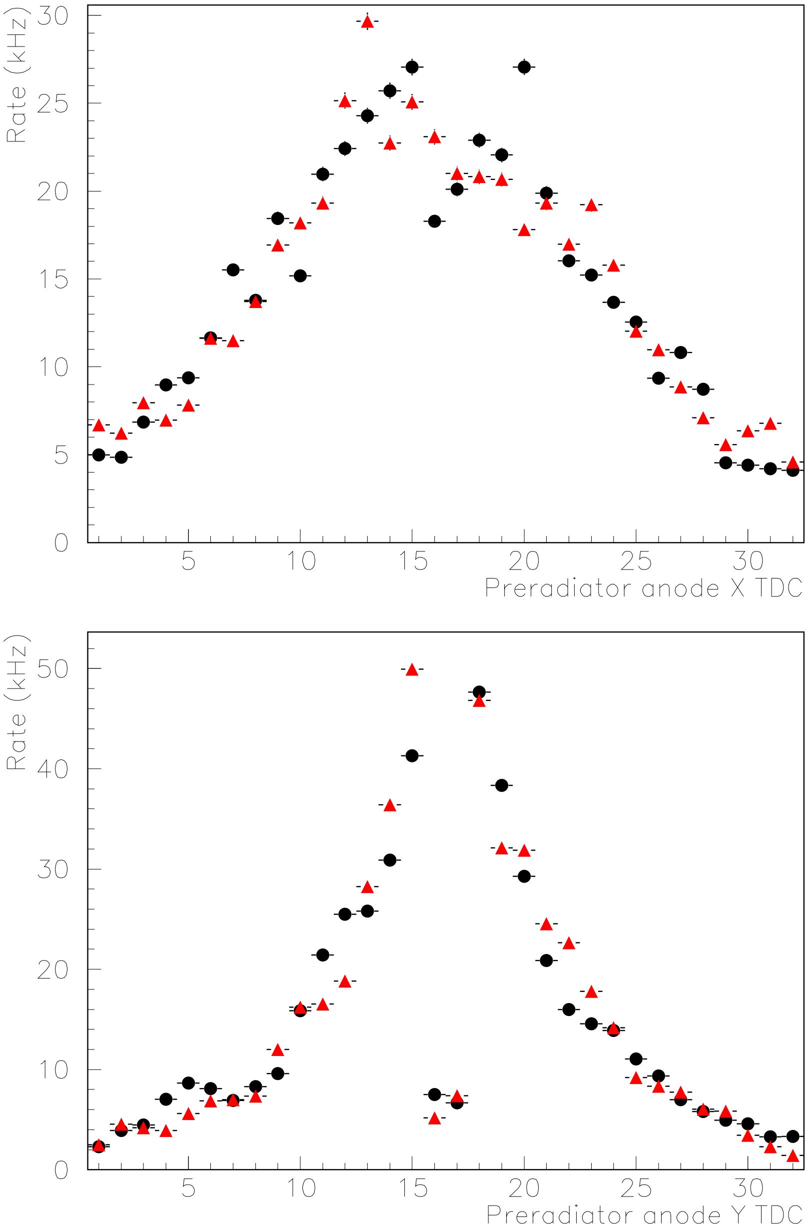


Figure 13: Preradiator anode singles rate (kHz) as a function of location. The top (bottom) plot is for the vertical (horizontal) wires. The binning is at the TDC level (24 wires). No energy threshold is applied. The rates are approximately independent of Z. Black dots: neutrons on, red triangles: neutrons off.

plying by 25 MHz and dividing by the number of channels (4 quadrants times 64 layers in Z times 24 wires per TDC).

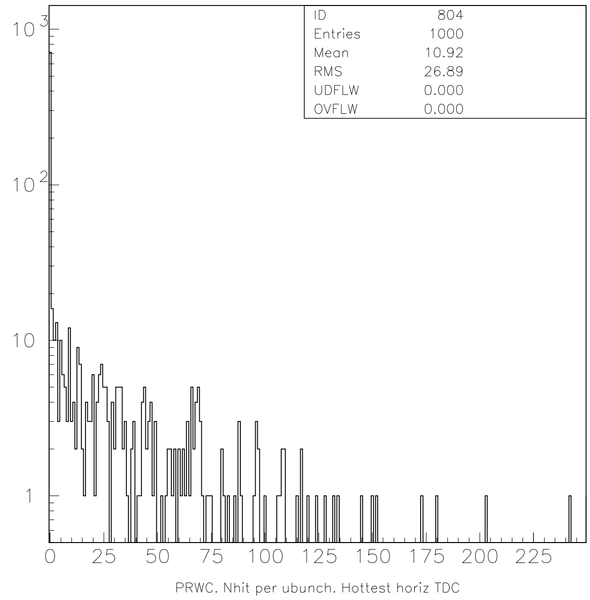


Figure 14: Number of hits per microbunch in the region of the hottest TDC for the horizontal preradiator wires.

# 5 DAQ data rate

One can get a rough idea of the DAQ data rates by assigning a number of bits to each subdetector hit. No trigger selection is applied. The rates per L1-accepted microbunch would presumably be higher than the minimum bias case; on the other hand, for each accepted microbunch, we anticipate reading out the preceding and succeeding microbunch which are presumably minimum bias. This is an update of the analysis in [3] in which hits in every piece of scintillator were counted, rather than summing them together in readout elements.

We assume that the WFD's produce 20 samples for every hit with 10 bits per sample, or 200 bits per hit. Preradiator anode hits are assumed to produce 32 bits per hit. Five cathode strips are assumed to be hit for each anode hit with 15 samples per cathode hit at 8 bits per sample. The following modules were assumed to be viewed by two phototubes: preradiator scintillator, upstream wall, downstream magnet veto, vertical veto and horizontal veto.

Figure 15 shows the DAQ data size per microbunch for the run with neutrons turned on. Taking the mean of Figure 15, a L1 accept rate of 1 MHz, and assuming we read out three microbunches for each L1 accept, the average DAQ data rate comes out to 23 Gbytes/sec.

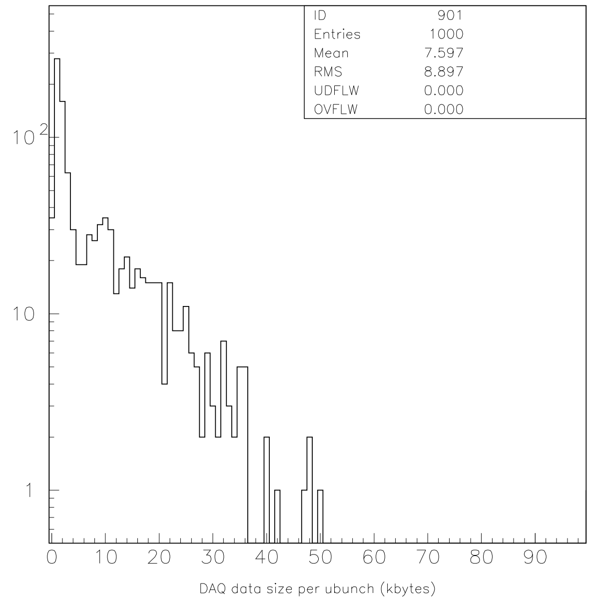


Figure 15: DAQ data size in kbytes per microbunch. No trigger selection has been applied. Neutrons are on.

# References


[1] H. Morii, slides shown at DS charged veto meeting, Oct. 8, 2004. (http://www.kopio.bnl.gov/meetings/DCV/oct08_04/)
H. Morii, slides shown at the December 2004 collaboration meeting.

[2] T. Nomura, private communication.

[3] G. Redlinger, slides shown at Thursday meeting May 6, 2004.