Technical Note
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Study of Rates in the Radphi Detector

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Abstract

A general survey of the rates observed in Radphi detector elements during the 2000 run is presented. Of special interest are the rates extracted for the BGD (barrel gamma detector) and the LGD for which no scaler information was collected. TDC information was used to provide rate information for the BGD. In the case of the LGD the rate information is extracted by a comparison of inclusive spectra collected during minimum-bias runs at high and low beam current. The results show an excellent agreement with Monte Carlo predictions for the rates from electromagnetic background alone. Evidence is seen for rate-dependent effects in the blocks nearest the beam hole.

Table 1: Signal rates, widths and dead-time factors for the major components of the Radphi detector. Rates shown are those obtained at full operating intensity.

signal	rate (Hz)	duration	dead-time fraction
taggerOR	$5.0 \cdot 10^7$	5 ns	0.07 [1]
cpvOR	$8.2 \cdot 10^7$		0.04 [2] [4]
bgdOR	$8.0 \cdot 10^5$		0.03 [3] [4]
upvOR	$0.9 \cdot 10^6$	40 ns	0.04
bsdOR-2	$6.4 \cdot 10^6$	10 ns	0.005 [5]
bsdOR-1	$2.7 \cdot 10^6$	10 ns	0.002 [5]
bsdOR-3	$1.8 \cdot 10^6$	10 ns	0.001 [5]
bsdAND	$7.9 \cdot 10^5$	20 ns	0.016
level-0 [6]	$5.8 \cdot 10^5$	10 ns	0.006
level-1	$2.7 \cdot 10^5$	1.2 μs [7]	0.31
level-2	$7.9 \cdot 10^3$	15 μs [8]	0.11
level-3	350	650 μs [9]	0.23

[1] based on 25 ns gate from individual channel discriminators
[2] based on 10 ns gate from individual channel discriminators
[3] based on 40 ns gate from individual channel discriminators
[4] this is a veto inefficiency, no effect on experimental live-time
[5] from 5 ns gate on individual channel discriminators
[6] level-0 denotes the level-1 logic signal before it is gated by the busy signal
[7] minimum dead time from receipt of level-1 gate to end of fast-clear when event fails level-2
[8] average dead time from receipt of level-2 gate to end of fast-clear when event fails level-3
[9] average event readout time

1 Timing and rates

The Radphi experiment ran for a total of about 1000 hr with photon beam on target. Data taking was divided into runs of 1-2 hr duration. Data were saved on local disk and then migrated offline to permanent storage on the Jefferson Lab Mass Storage System. An average of 350 events were collected by the data acquisition system per second. The average event record size was 600 bytes, leading to a modest data rate of 200 kB/s. The photon source was operated with two bremsstrahlung radiators throughout the course of the run. For approximately the first half of the period, a radiator of nominal $2 \cdot 10^{-}4$ radiations lengths thickness was used with an electron beam current of 130 nA. For the second half the radiator thickness was increased to $3 \cdot 10^{-}4$ radiation lengths and the electron beam was turned down to 77 nA. At a distance of 40 m from the radiator, the Radphi target of radius 12.8 mm intersected over 95% of the photon beam. When the Radphi target was moved out of the beam, rates in the detector scintillator elements dropped by about one order of magnitude.

All of the signals that are relevant to the event trigger are listed in Table 1. The gate for the ADC's and TDC's was generated from the level-1 trigger. The high rate in the *cpvOR* prevented its use as a veto in the online trigger. The total proton photoproduction cross section integrated over the bremsstrahlung spectrum of the beam from pion threshold to the end-point leads to a total hadronic rate in the Radphi target of 150 kHz. Increasing this rate by a factor of two to account for neutron photoreactions still does not approach the order of magnitude of the observed rates in the bsd and cpv.

Geant-based Monte Carlo simulations of the Radphi experiment, including the beam line, predict rates in agreement with those shown in Table 1 coming from electromagnetic backgrounds alone. Most of the rate of charged particles coming from showers originating in the target is confined to angles a few degrees from the beam but the tails of this distribution extend out as far as 60°, accompanied by a diffuse omni-directional background of low-energy deltas and gammas. The energy distribution of this background peaks in the MeV region, except for the area immediately surrounding the forward beam hole where the typical energies are tens of MeV. The hard component coming from conversions in the target escape through the forward beam hole and do not affect the experiment. Evidence that backgrounds of this sort are the dominant contribution to the rates in the trigger counters is seen in the marked decrease in Table 1 going from the innermost bsd layer *bsdOR-2* to the middle and outer layers. These three layers are in immediate contact with each other, with only the material of 5 mm of plastic plus two layers of tape shielding an outer layer from the flux seen by its inner neighbor. The fact that such a small amount of material led to a decreasing in the observed rate by nearly a factor of two indicates that the source of the rate is primarily MeV-scale background.

The hit rate in the bgd was a strong function of threshold. During the early stages of the run, the bgd counters were operated at a low threshold corresponding to an electron-equivalent energy of 5 MeV. Under these conditions the total rate in the bgd was 800 kHz at standard operating intensity, as shown in the table. The bgd gains were lowered later by a factor of 4 later in the run, effectively raising the thresholds to 20 MeV. This reduced the inclusive bgd rate to 120 kHz, in agreement with expectations based upon a total nuclear interaction rate of 300 kHz and 40% solid angle for the bgd acceptance. This observation is consistent with Monte Carlo simulations which show that the background rates in the barrel are dominated by hadronic sources at energies above 20 MeV. This is considered an effective lower bound on the energy of showers that may be reconstructed in the bgd.

There were no scalers or TDC's on the LGD signals so there is no direct measurement of the rates in the forward calorimeter. Instead these rates have been inferred from the increase with beam current in the observed energy for a given block within the ADC gate. A minimum-bias trigger was formed by disabling levels 2 and 3 and accepting all level-1 events. By deriving the trigger from barrel and tagger elements only, an unbiased view of what is happening in the forward is obtained. This view contains two components, one which is correlated to what caused the trigger in the barrel (hadronic events are likely candidates) and the other which is uncorrelated with the barrel and consists of random forward hits that happen to fall within the 140 ns of the ADC gate. These two components are distinguished by running two minimum-biased runs under unchanged beam conditions, one at full beam intensity and the other at low intensity. For the comparison shown below, the low-intensity run was carried out at 2 nA electron beam current in comparison with the full intensity of 77 nA.

The rate in a block is defined as the fraction of events within a given data set for with the block's ADC is over threshold divided by the gate width. This rate is the sum of the barrel-correlated component which does not depend on beam current (a constant probability divided by a constant gate width) and the barrel-accidental part which is linear in beam current and disappears in the limit of low rate. When the beam current was turned down from 77 nA to 2 nA the rates across the LGD decreased by only a factor of about 8 instead of the factor of 38 expected if only accidentals were present. On the other hand, if only barrel-correlated hits were present in the LGD then this rate should have been independent of beam current. This shows that at 77 nA the LGD inclusive rates are accidentals-dominated and at 2 nA they are dominated by the barrel-correlated component.

Within errors, the inclusive LGD rate that would be measured on a free-running scaler connected to each block is simply the difference above-defined block rates between the high and low-intensity runs. These rates are plotted as the data points in Fig. 1a as a function of the distance of the block from the beam axis. The histogram in the figure is the Monte Carlo estimate for the LGD rates arising only from electromagnetic background. Note that for individual blocks, the expected hadronic rate is negligible on this scale. The excess of the data over Monte Carlo at large radius suggests that there are sources of background in the experimental hall that are not included in the simulation. The simulation includes the principal components of the hall B photon beam line starting at the radiator and including the (empty) CLAS target and downstream yoke aperture. It was on the basis of this simulation that the helium bag and lead shielding wall upstream of the Radphi experiment were introduced. An excellent agreement between observed and predicted rates is seen across the face of the LGD. The ADC threshold used in the Monte Carlo for this comparison is 15 MeV, which corresponds to the online threshold that was applied to the LGD data by the data acquisition.

Note that in Fig. 1a a marked depression appears in the observed rates relative to expected at small radius. These blocks are in the vicinity of the beam hole and, in addition to suffering from the highest rates, these blocks also suffered from radiation damage. The eight blocks closest to the beam axis (first data point) are the most affected, but some effects can be seen at neighboring points. These data which were were taken toward the end of the Radphi run period provide a quantitative measure of the effects of radiation damage on the response of the LGD. More insight can be provided by the pulse-height spectrum of these background hits in the minimum-bias sample. All of the spectra show a maximum intensity at threshold and an exponential tail that extends to the GeV region. The mean of this distribution is plotted in Fig. 1b as a function of block distance from the beam axis. As in Fig. 1a the points are the data and the histogram is

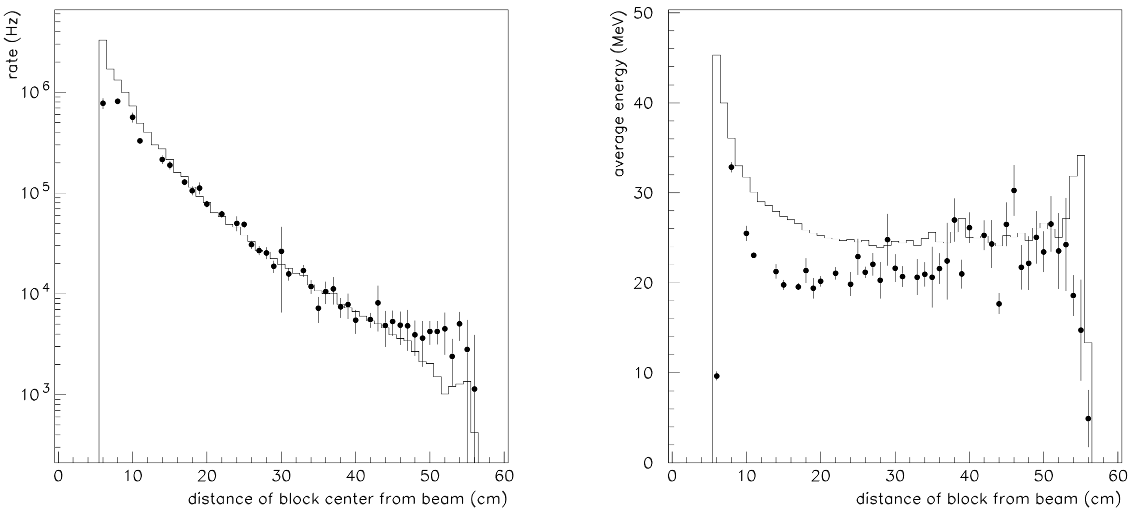

Figure 1: Characteristics of unbiased flux observed in individual blocks in the LGD as a function of distance from the beam. The points are derived from data and the histograms from a Monte Carlo simulation of the electromagnetic background coming from the beam and target. Rates (left panel) and average energy (right panel) include all hits over 15 MeV.

the Monte Carlo prediction. The comparison is sensitive to the exact threshold used, which was 15 MeV for Monte Carlo but varied between 10 MeV and 20 MeV for real data, depending on the channel. Even with this caveat, the general trends are very similar between data and Monte Carlo, including the forward rise that is expected based upon the kinematics of electromagnetic showers. The depression of the response on the innermost blocks is due in part to radiation damage, but also to the fact that these blocks contained so much background that the calibration procedure tended to artificially suppress their gains relative to their neighbors in the interest of optimizing the total shower energy resolution.