HCal Energy Deposition Study

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Introduction

This document describes the expected energy deposition in the HCal scintillators for each of the seven G_M^n kinematics. The goal of this analysis is to estimate the maximum energy deposited in a single PMT for each kinematic. This will make it possible to calibrate HCal's PMT HV so as to not saturate the fADCs during events in which the maximum energy for a kinematic is deposited in a single PMT. These calculations will also be performed for the maximum total energy deposited in an entire event in case it were decided that recording the summing module output to the fADCs would be useful.

Simulation Methodology

These values were determined using G4SBS simulations of the full G_M^n experiment. Each kinematic was simulated according to the run plan with 10,000 elastic electrons incident upon a 15 cm LD_2 target at 44μA. The placement of HCal and other equipment was set in accordance with the run plan. Electrons were generated in a wide area to fully cover the acceptance. The electrons were generated with $\theta = \pm 10^\circ$ of the BigBite set angle and $\phi = \pm 30^\circ$.

Simulation Results

Table 1 gives the results of the energy deposition study. The column titled *Kine* gives the Q^2 value for each of the seven G_M^n kinematics in GeV^2. The *HCal Events* column gives the number of events that reached the HCal to be recorded. The *Total Hits* column gives the total number of hits across all events for the run. The *PMT with Max Edep* column lists the row and column number of the PMT in which the maximum energy was deposited (row and column numbers begin counting from zero). The *Max Edep in PMT* column gives the maximum energy deposited in a single PMT during the run in MeV. The *NPE for Max Edep in PMT* column gives the number of PE expected to be seen by the PMT with maximal energy deposition. It is assumed from previous simulation results that there are ≈5.5 PE per MeV. The *Max Edep All PMTs* column gives the maximum energy deposited in all PMTs for a single event in MeV. Note that this event is generally not the same event in which the maximal energy was deposited in a single PMT. The *NPE for Max Edep All PMTs* gives the number of PE deposited in all PMTs for a single event (≈5.5 PE per MeV).

Kine [GeV^2]	HCal Events	Total Hits	PMT with Max Edep [row-col]	Max Edep in PMT [MeV]	NPE for Max Edep in PMT	Max Edep All PMTs [MeV]	NPE for Max Edep All PMTs
3.5	5082	11747	r13c5	267	1469	407	2236
4.5	6070	18859	r12c4	308	1694	465	2559
5.7	7690	30942	r11c1	418	2302	493	2712
8.1	7874	38803	r14c3	497	2733	726	3893
10.2	7539	41205	r10c3	570	3132	797	4383
12.0	8781	53540	r18c7	669	3682	960	5280
13.5	6711	34567	r10c0	740	4070	977	5373

Table 1. Maximal energy deposited in a single PMT and entire event for each of the seven G_M^n kinematics.

Data Analysis for PMT HV Calibration

The signals out of the HCal PMTs pass through a 10x amplifier on the front end. One copy of this signal is then sent to the fADCs over a long (100m) cable. The fADCs have an adjustable dynamic range of 0.5 V, 1 V, and 2 V which are selected using jumpers on the fADC board itself. Assuming the 2 V fADC range is used then any signals out of the amplifier up to 2 V can be recorded without saturating the fADCs. This means that the maximum allowable signal out of a single PMTs is 200 mV (200mV * 10 = 2 V) without saturating the fADC channel. Note that this is with neglecting the signal degradation over the long cables. Attenuation studies were performed for the long cables by CMU. Unfortunately, I do not currently have these results, but I believe that the long cables attenuated the signal by a factor of ≈2 times. This document will be updated when a more reliable number is found.

A second copy of the PMT signal out of the 10x amplifiers goes to a 50-50 splitter panel. Of the two outputs from the splitter panel one goes to the F1TDCs and is not relevant for this analysis. The other output with 50% of the amplified signal goes to the summing modules. These modules sum 4x4 blocks of HCal PMT signals. Their output can be used as a trigger but it could also be sent to an fADC to be recorded if desired. Neglecting the long cable attenuation again, the summing modules can output a maximum of 2 V of signal from the 16 PMT signals they sum without saturating the fADCs. Since the inputs to the summing module come from a 50-50 splitter after the 10x amplifier that means a maximum combined signal from the 16 summed PMTs can total 400 mV before saturating the fADC channel. For this analysis we will consider all of the energy to have been deposited in the 4x4 block of PMTs going to the summing module to represent the most energy that could be summed at once.

Table 2 gives the maximal signal allowed out of the PMTs without saturating the fADCs based on the maximum energy deposited in the scintillators. The column titled *Kine* gives the Q^2 value for each of the seven G_M^n kinematics in GeV^2. The *Max Edep in PMT* column gives the maximum energy deposited in a single PMT during the run in MeV. The column titled *Max mV/MeV from PMT [2 V/1.5 V]* gives the maximum signal in mV that can be produced from the PMT per MeV deposited in the scintillator without saturating the fADC. Two values are given. The first is assuming the full 2 V range of the fADC is utilized and the second assuming only 1.5 V of the fADC range is used to allow for some overhead. The column titled *Max mV/MeV from PMT with Attenuation [2 V/1.5 V]* gives the same value as the previous column except for it accounts for a factor of two attenuation due to the long BNC cable. The *Max Edep All PMTs* column gives the maximum energy deposited in all PMTs for a single event in MeV. The *Max mV/MeV All PMTs [2 V/1.5 V]* column gives the maximum signal in mV that can be produced from all PMTs per MeV deposited in the scintillator without saturating the fADC. Again, a value for an fADC range of 2 V and 1.5 V is given. Finally the *Max mV/MeV All PMTs [2 V/1.5 V] with Attenuation* column is the same as the one preceding it except that it accounts for a factor of two attenuation due to the long BNC cable.

Kine [GeV^2]	Max Edep in PMT [MeV]	Max [mV/MeV] from PMT (2 V/1.5 V)	Max [mV/MeV] from PMT with Cable Attenuation (2 V/1.5 V)	Max Edep All PMTs [MeV]	Max [mV/MeV] All PMTs (2 V/1.5 V)	Max [mV/MeV] All PMTs with Cable Attenuation (2 V/1.5 V)
3.5	267	0.75/0.56	1.50/1.12	1407	0.98/0.74	1.97/1.47
4.5	308	0.65/0.49	1.30/0.97	465	0.86/0.65	1.72/1.29
5.7	418	0.48/0.36	0.96/0.72	493	0.81/0.61	1.62/1.22
8.1	497	0.40/0.30	0.80/0.60	726	0.55/0.41	1.10/0.83
10.2	570	0.35/0.26	0.70/0.53	797	0.50/0.38	1.00/0.75
12.0	669	0.30/0.22	0.60/0.45	960	0.42/0.31	0.83/0.63
13.5	740	0.27/0.20	0.54/0.41	977	0.41/0.31	0.82/0.61

Table 2. PMT output signal limits for each of the seven G_M^n kinematics with fADC ranges of 2 V and 1.5 V and with and without signal attenuation due to the long cables.