# SHMS Heavy Gas Cherenkov (HGC) Detector Checkout

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During commissioning the SHMS HGC detector will be filled with $CO_2$ at 1.00 atm with refractive index 1.005. The experts in charge will be Garth Huber, and Ryan Ambrose.

## 1 HGC Detector Initial Checkout

Expected time: 1 hour
**Goal: check signal timing and fADC thresholds**
Conditions:

- Beam: 2.2 GeV, 5-20 $\mu$A, fast rasters off
- Target: 0.5% carbon
- Collimator: SHMS collimator
- Trigger: SCIN $\frac{3}{4}$
- SHMS angle: $25^o$
- SHMS momentum: -1.6 GeV/c

Based off the signals from KPP run 488 new voltages are set to align the single photoelectron peaks to 6.825 pC, or ADC channel 350 , in the goodAdcpulseInt spectra.

◇ PMT 1: 2251 V

◇ PMT 2: 2047 V

◇ PMT 3: 2001 V

◇ PMT 4: 2096 V

This can be verified in two ways: checking the DEF-file phgcer_good_pi_vs_pmt and ensuring the dark horizontal band above zero align about 6.825 pC (Figure 1), or my checking the ntuple leaf P.hgcer.goodAdcPulseInt for each PMT and verifying the single photoelectron peak is centred at 6.825 pC (Figure 2). If there are any discrepancies the HV will be altered to tune the gain between all four PMTs. The formula to determine the new HV setting is

$$V_{\text{new}} = V_{\text{old}} \left( \frac{\text{Peak Charge}_{\text{new}}}{\text{Peak Charge}_{\text{old}}} \right)^{\frac{1}{n}}$$

where the values of $n$ are PMT specific parameter,

- ◇ PMT 1: 10.72
- ◇ PMT 2: 10.86
- ◇ PMT 3: 10.57
- ◇ PMT 4: 8.54

Timing signals from both the fADC and TDC 1190 for the HGC will be checked. During KPP runs the timing signal showed an anomalous double peak which can be observed in Figure 3. During this run period the fADC's will have 'multi-hit' mode enabled which should allow the double peaking to be attributed to a reflection or ringing on a large pulse. fADC thresholds will be checked as well.

(eep) Coincidence
Expected Time: 1 hour
**Goal: further check of HGC response to electrons**
Conditions

- ◇ Beam: 2.2 GeV, 5-60 $\mu$A, fast rasters 1×1 mm
- ◇ Target: 10 cm LH2, 10 cm Dummy
- ◇ HMS/SHMS Collimator: PION/COLLIMATOR
- ◇ HMS/SHMS Trigger: SCIN $\frac{3}{4}$/SCIN $\frac{3}{4}$
- ◇ HMS/SHMS angle: $62.5^o/25.1^o$
- ◇ HMS/SHMS momentum: -0.938 GeV/c & +1.997 GeV/c

Since protons are not able to Cherenkov in the HGC under these conditions, this will provide more time to check the HGC response to electrons.

# 2 Detailed Detector Checkout

Expected Time: 2-4 hours
**Goal: Gain matching, calibration, efficiency**
Conditions:

- ◇ Beam: 6.4 GeV, 5-20 $\mu$A, fast rasters off
- ◇ Target: 0.5% carbon
- ◇ Collimator: centred sieve (at $25^o$) and collimator (at $15^o$)
- ◇ Trigger: SCIN $\frac{3}{4}$
- ◇ Angle and Momentum: $25^o$, -1.6 GeV/c
- ◇ Angle and Momentum: $15^o$, -3 GeV/c

Under these conditions a pion signal should be obtainable in the HGC and so particle ID cuts placed on the pre-shower and calorimeter can be used to separate the signal from electrons and pions. This can be used to further test if the HGC is gain matched. Once a larger data file is obtained ( 1M events) the data will be re-calibrated using the script located in the hallc_replay directory. The calibration constants will then be updated, the data replayed once again and the resulting photoelectron spectra will be compared to KPP data. The efficiency of each PMT and the entire HGC can also be determined, and compared to older data. At this point, the systematics in the calibration and gain can be investigated by changing the HVs by $\pm$ 50 V.

Defocused Run SHMS
Expected Time: 2-4 hours
**Goal: coordinate dependencies of detector's responses**
Conditions:

- Beam: 6.4 GeV, 5-20 $\mu$A, fast rasters off
- Target: 0.5% carbon
- Collimator:SHMS collimator
- Trigger: SCIN $\frac{3}{4}$
- Angle: $15^o$
- Momentum: -3 GeV/c

Take high statistics runs to get detailed X and Y coordinate dependencies of each PMT and entire detector. Can also investigate the 2-dimensional HGC x,y-plane to check to localized inefficiencies. To examine this spectra, in a ROOT session one plots the histogram 'P.hgcer.npe:HGC_ypos:HGC_xpos' with cuts '-40<HGC_ypos<40', '-50<HGC_xpos<50', and '0<P.hgcer.npe<20'. Here, HGC_ypos and HGC_xpos are the projections from the focal plane into the HGC plane from the equation

$$\text{HGC\_ypos} = \text{P.tr.y[0]} + \text{P.tr.ph[0]} * 156.27$$
$$\text{HGC\_xpos} = \text{P.tr.x[0]} + \text{P.tr.th[0]} * 156.27$$

one can then examine the relationship between NPE and position via the 'Project3D' function or the 'Project3DProfile' function. An example plot is given in Figure 4.

(eep) Coincidence Runs
Expected Time: 2-4 hours
**Goal: determine delta electron background**
Conditions:

- Beam: 2.2, 6.4 GeV, 5-20 $\mu$A, fast rasters off
- Target: 0.5% carbon
- Collimator:SHMS collimator
- Trigger: SCIN $\frac{3}{4}$
- SHMS angle and momentum: $25.1^o$, +1.997 GeV/c
- SHMS angle and momentum: $27.5^o$, +3.609 GeV/c

For 2.2 GeV/c the positrons will Cherenkov, but their rates are negligible. So light detected from the HGC are due to delta electrons produced by pions or protons. At 6.4 GeV/c the pions will start to Cherenkov, but only produce around one photoelectrons. Higher photoelectron signals must also be due to delta electrons.

## 3 Calibration/Efficiencies Scripts

The following procedure is assumed to be offline, and that the user has an up-to-date version of the Hall C directories hcana & hallc_replay.

- ◇ Replay the desired run using hcana (100000 events or more is sufficient)
- ◇ Place replayed .root file in directory hallc_replay/ROOTfiles
- ◇ Run the script CALIBRATION/shms_hgc_calib/run_cal.C (refer to README for more information)
- ◇ If newly generated calibration constants are sufficient, the script will automatically update the appropriate PARAM file
- ◇ When the run is replayed, it will now have the proper NPE spectra
- ◇ To investigate efficiencies, run the script run_cal.C with the properly calibrated run
- ◇ As an option, enter a decimal number as the number of photoelectrons to cut on (e.g. 1.5)

# 4 Appendix

## 4.1 Gain Matching

Proper gain matching of each HGC PMT is important to ensure the photoelecton peaks are spaced out sufficiently as to discern between them while staying within the ADC range of channels. As well, each PMT should be set to the same gain so they have the same response to incident light. To calculate the gain first one must know the charge recorded per ADC channel, as of now the HGC readout has 1 V distributed over 4096 channels and the pulse is sampled at a 4 ns rate.

$$Q = \frac{V\Delta t}{R} = \frac{(1\ V)(4\ \mathrm{ns})}{(50\ \Omega)} = \frac{8.0\times 10^{-11}\ \mathrm{C}}{4096\ \mathrm{ADC\ Channels}} = 1.95\times 10^{-2}\ \mathrm{pC/Channel} \tag{1}$$

to determine the gain one can use the formula

$$\mathrm{Gain} = \frac{Q\ [\mathrm{N^{th}\ Peak\ Channel}]}{\mathrm{N}(1.602\times 10^{-7}\ \mathrm{pC})} \tag{2}$$

where $Q$ is given by Equation 1 and N refers to a particular photoelectron. For the HGC to be perfectly gain matched, all four PMTs should get the same ADC channel peak for the single photoelectron peak. An appropriate channel is 350, this gives sufficient spacing from low-level signals while accommodating up to 10 photoelectrons. Using Equation 2 this gives a Gain $\sim 4.260\times 10^{7}$ which gives the ADC channel peak for 10 photoelectrons as 3500. Using data from the KPP run 488, one can determine the appropriate voltage for gain matching by the formula

$$V_{\mathrm{new}} = V_{\mathrm{old}}\left(\frac{\mathrm{Peak\ Channel_{new}}}{\mathrm{Peak\ Channel_{old}}}\right)^{1/n} \tag{3}$$

where $n$ is a PMT specific parameter, determined from previous runs to be

| PMT | PMT 1 | PMT 2 | PMT 3 | PMT 4 |
|---|---|---|---|---|
| $n$ | 10.72 | 10.86 | 10.57 | 8.54 |

plugging these values into Equation 3 with run 488 and the previously discussed desired photoelectron spacing gives for initial HGC PMT voltages

| PMT | PMT 1 | PMT 2 | PMT 3 | PMT 4 |
|---|---|---|---|---|
| Voltage | 2251 | 2047 | 2001 | 2096 |

which explains the initial voltages chosen in the procedure.

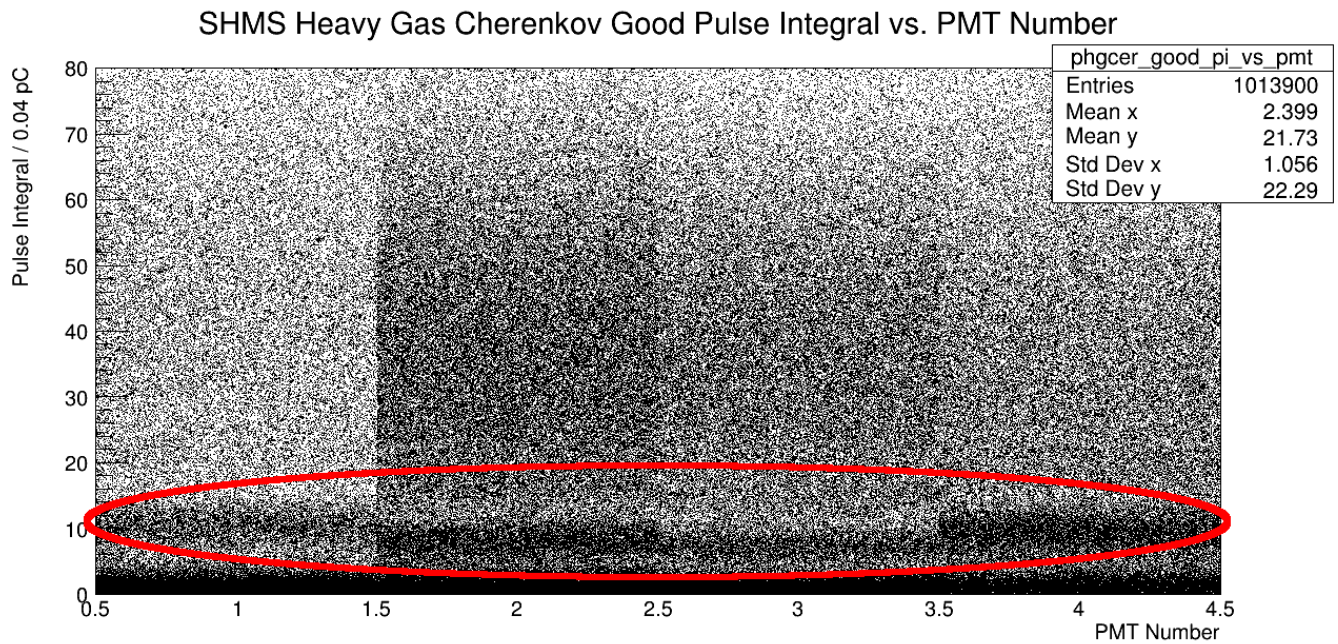


Figure 1: ROOTfile DEF-file phgcer_good_pi_vs_pmt. Along the x-axis is PMT number (from 1 to 4), the y-axis is charge in pC. Circled in red is the single photoelectron peak. To verify the PMTs are properly gain matched, each band should align to the same value so that a single black band is observed.

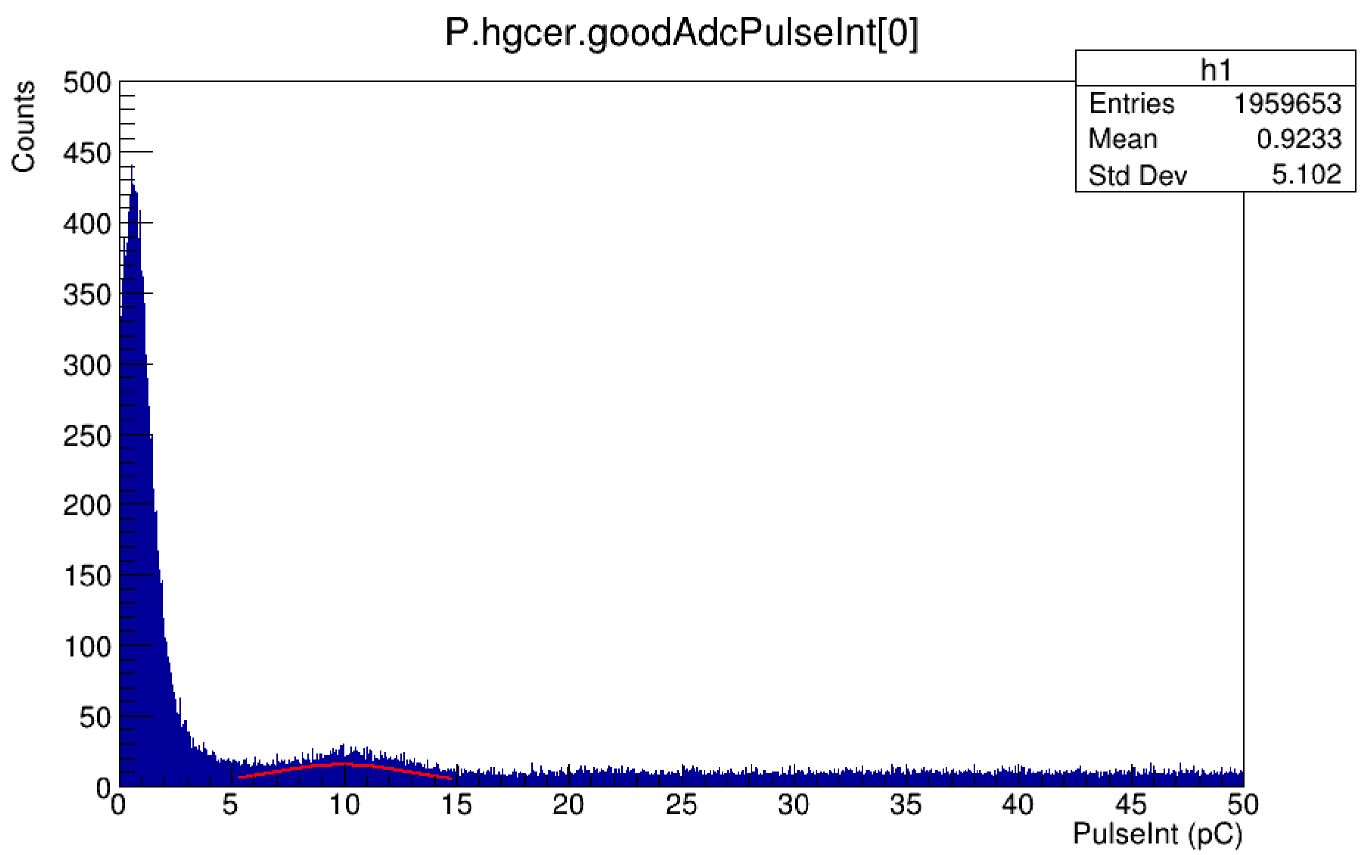


Figure 2: ROOTfile leaf P.hgcer.goodAdcPulseInt[0]. Along the x-axis is charge in pC, y-axis is counts. The single photoelectron is fit with a red Gaussian (from FitPanel) to precisely check location of the peak. Using this method, each PMT must be checked separately.

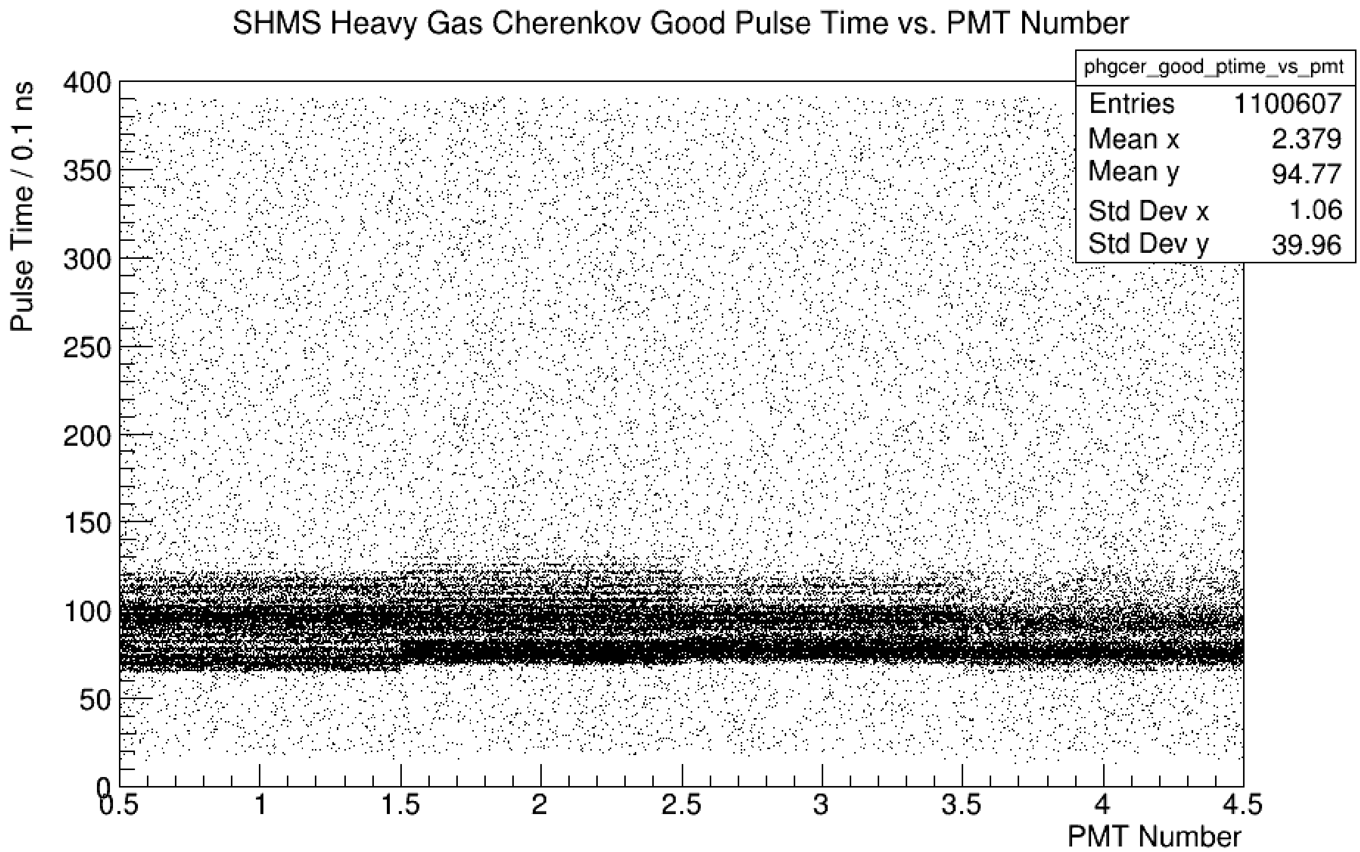


Figure 3: ROOTfile DEF-file phgcer_good_ptime_vs_pmt. Along the x-axis is PMT number (from 1 to 4), the y-axis is time in ns. Two dark bands are observed about 100 ns and 70 ns.

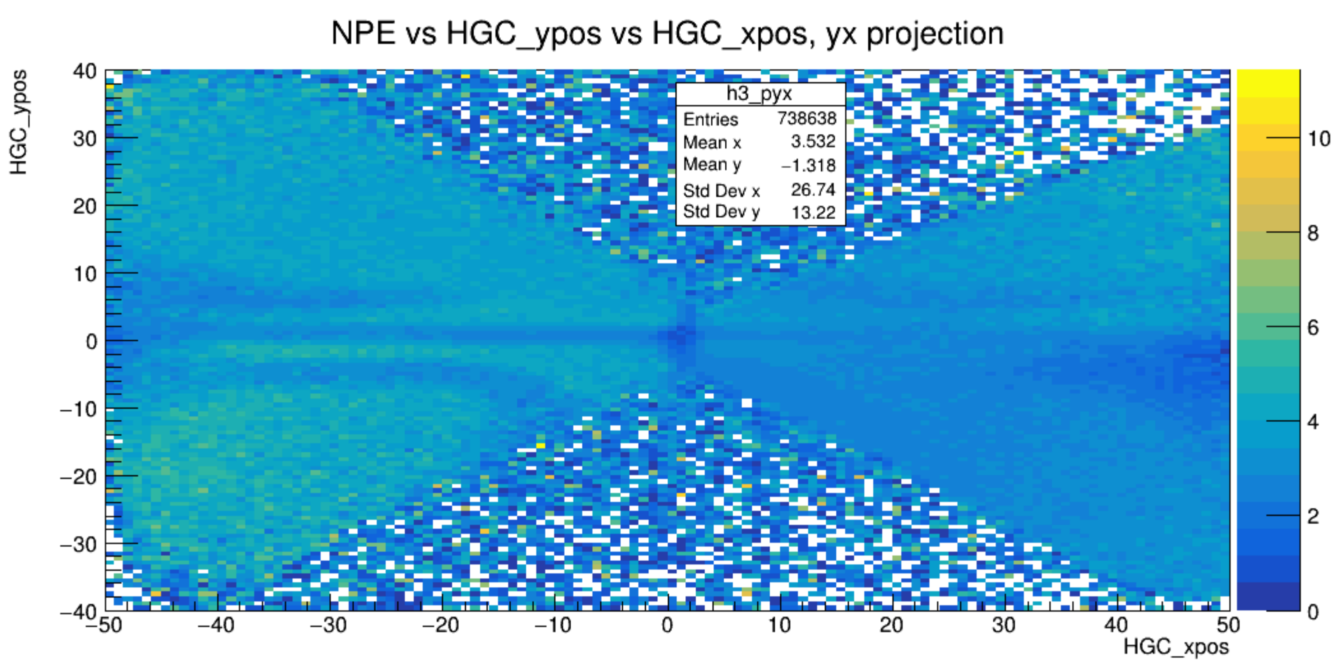


Figure 4: Histogram "P.hgcer.npe : HGC_ypos : HGC_xpos" , "0<P.hgcer.npe<20 && -40<HGC_ypos<40 && -50<HGC_xpos<50" projected into the "yx" plane. HGC_ypos and HGC_xpos are defined in the text. Of particular note are regions of localized lower counts.