Summary of SHMS Quartz Hodoscope ET9814QB+base Modelling

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The main purpose of the modelling was to understand what nominal HV setting to use, and how much gain we have in reserve. As the gain of the PMT's drops over years of use, we'll want to increase the HV. At some point that will no longer be possible because we'll exceed the rating of something in the base or the PMT.

These PMTs may have higher gain on average than the catalog specs. (See Figures below. The second is a zoomed version.) On these plots I've included only 3 of the PMTs measured by Simona Malace and Sam Danagoulian. I converted their spe pulse heights in https://logbooks.jlab.org/entry/3415196 to an apparent gain assuming a 50 Ohm load and an estimated 10 ns wide pulse. I assume the spread in gains is real and not due to errors in base assembly because the divider currents agree well at the same voltage.

The first question is, "**What is the nominal operating HV?**" For now, I'll assume a nominal gain target of $1x10^7$ (about 8 mV average pulse height for the spe). This choice is a trade-off based on reports of a low-ish number of pe's and the instability of these tubes as they approach their max gain of 3E7. From the Gain vs Voltage plots below, the typical operating voltage should be 1650V. Due to gain variation from tube to tube, actual voltages will range at least +-100V about this typical value.

The second question is, "**What is the maximum HV**?" I'm taking the nominal HV max as "the lower of 2500V or when the PMT reaches the manufacturer's maximum gain rating of $3x10^7$". Until these tubes age for years, the latter restriction will be more important; it corresponds to a spe average pulse height of 24 mV. There appears to be nothing in the base that will burn out even with the full 3kV maximum of our CAEN supplies. However, above 2500V the Vmax for K-D1 will be exceeded.

The next question is, "**How much gain reserve do we have**?" Even for a worst-case low gain PMT, it looks like we have a factor of ~50 reserve. I.e., if one of the lower gain PMTs now operates at 1750V, then as the tube ages the voltage can be increased up to 750V before we hit the maximum of 2500V. Since the gain slope near the operating point is about x1.7/100V, our reserve gain is $(1.7)^{750V/100V} = 54$. If we keep the anode currents low and avoid Helium poisoning, these PMTs may last the lifetime of the facility.

The output files contained in this same Hall C docDB entry are

- SHMSquartzHodoET9814QBGainvsVoltageModel_longoutput.dat
- SHMSquartzHodoET9814QBGainvsVoltageModel_shortoutput.dat
- SHMSquartzHodoET9814QBGainvsVoltage.pdf
- SHMSquartzHodoET9814QBGainvsVoltageZoomed.pdf
- SHMSquartzHodoET9814QBGainvsVoltage.xlsx

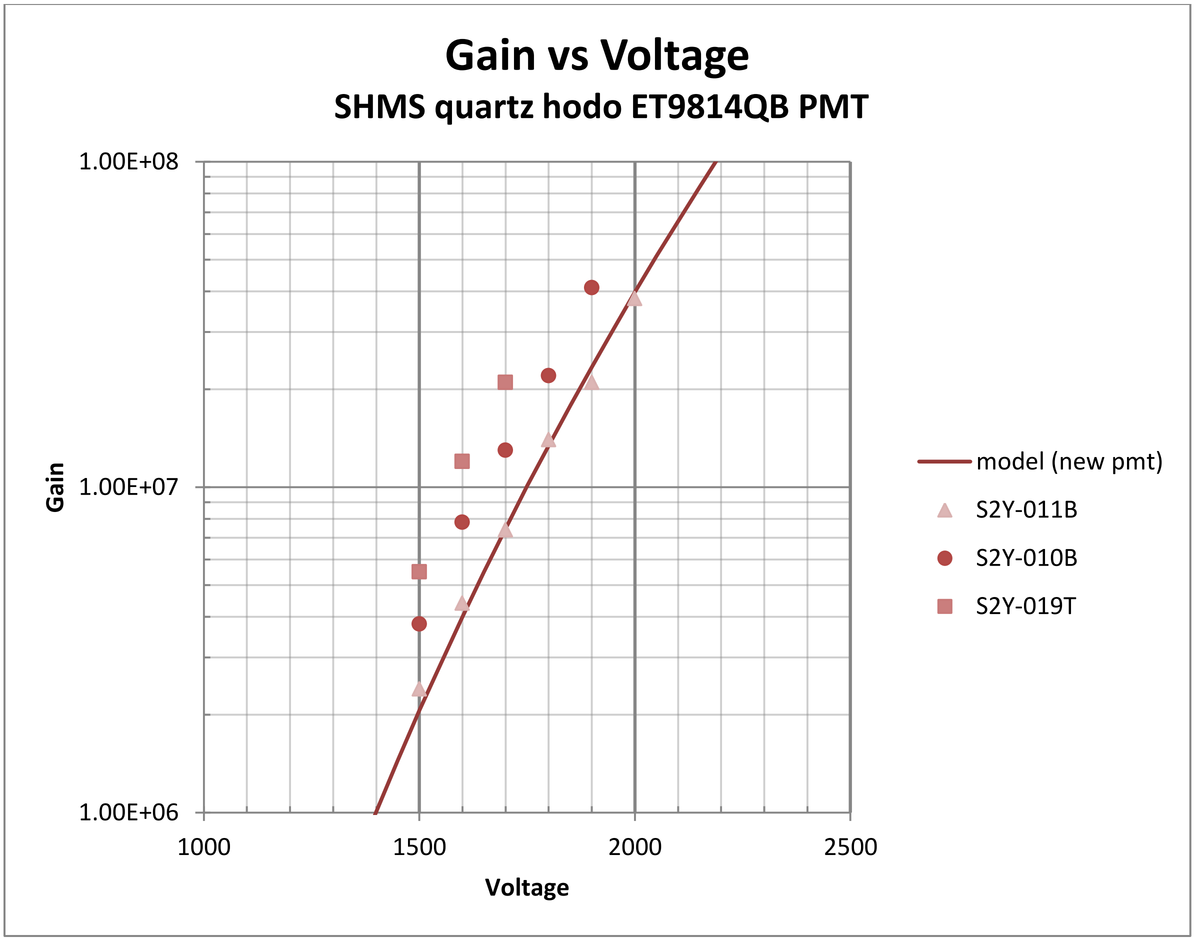
Comments:

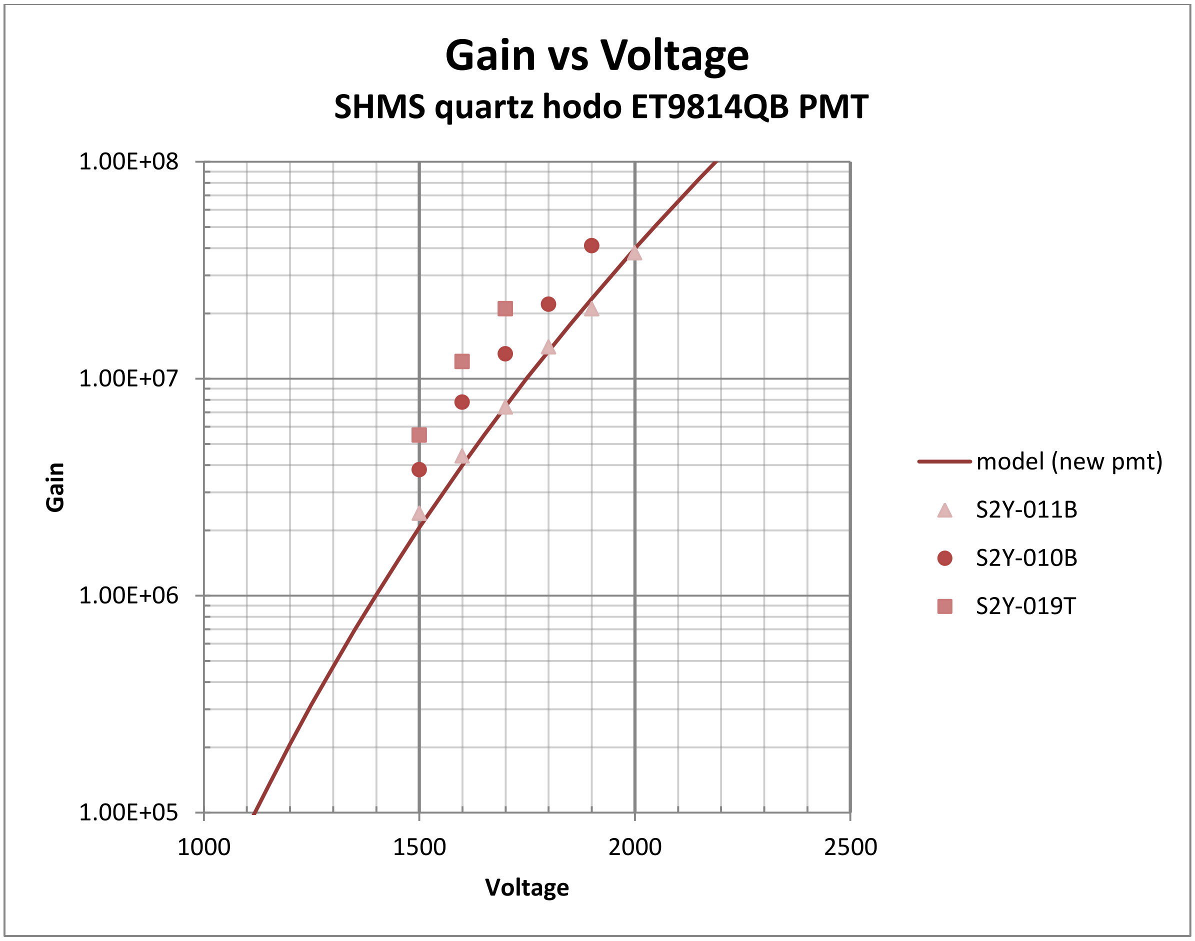
- The base is a gain-optimized divider. The chosen resister values provide a relatively low divider current of 0.33mA at the nominal HV setting. I anticipate the divider contribution to the gain stability will be adequate until the rate surpasses 100 KHz/paddle. (E.g., if a single paddle sees a 100 KHz rate at 1x107 gain with 50 pe's per PMT, then the anode current will be 8muA or 2.4% of the divider current.)
- Regarding the AC coupling of this positive HV PMT: The time constant for bleed-down of charge collected on the anode is tau = RC = 100KOhm x 4.7nF = 0.47 msec. We therefore might see small pedestal shifts at high rates. The FADC firmware measures a real-time pedestal so this should be no problem.

Methods:

My program GvsV_version6.f was used to model the gain and resistor power dissipations. It assumes the gain for each active stage is given by $g_i = \beta V_i^{\alpha}$. With some tedious algebra, I extract the two parameters α and β from the manufacturer's curve for the Divider A (or "standard divider"). The actual base we are using is the ET638A. It is what I would call a "gain optimized, resistive divider". (See table below with differences highlighted in red.)

	k-d1	d1-d2	d2-d3	d3-d4	d4-d5	d5-d6	d6-d7	d7-d8	d8-d9	d9-d10	d10-d11	d11-d12	d12-anode
Our base (ET638A)	3R	1R	1R	1R	1R	1R	1R	1R	1R	1R	1R	1R	1R
Divider A	300 V	1R	1R	1R	1R	1R	1R	1R	1R	1R	1R	1R	R


Gain vs Voltage
SHMS quartz hodo ET9814QB PMT
1.00E+08
1.00E+07
1.00E+06
Gain
1000
1500
2000
2500
Voltage
model (new pmt)
S2Y-011B
S2Y-010B
S2Y-019T



Gain vs Voltage
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Gain
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