Summary of HMS Hodoscope XP2262+base Modelling

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The main purpose of the modelling was to estimate 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 PMT's have been in use in the HMS for years, so "**What is the nominal HV?**" is not the priority question it is for the new detectors. However, from the plots below (one is just a zoomed version of the other), Simona Malace and her team found they typically achieve my nominal gain target of $5x10^6$ gain at 1800V.[1] That gain was adequate when these 1 cm thick scintillators were new. Since then, some scintillators may have deteriorated, but changes to the upstairs electronics may now allow a lower threshold.

As for the question, "**What is the maximum HV?**" We start exceeding the ¼W rating of one resistor near 2350V, so I'm taking the max HV as 2300V or when the PMT reaches the manufacturer's gain rating of $2x10^8$". Note that at this HV, we are far from running into limits from the CAEN HV channels or the PMTs themselves.

The next question was, "**How much gain reserve do we have**?" Assuming the initial operating voltage is about 1800V, and given that we can run these bases as high as 2300V, then the model suggests we have a factor of 2**5 = 32 gain in reserve. The highest two data points may indicate some sort of saturation that is missing in the model, but we still have at LEAST a factor of 2**3 = 8 gain in reserve. So if we don't set the gains too high, and can avoid helium poisoning, then these tubes may last the lifetime of the HMS. If a paddle has an unusually low signal, despite the spe gain appearing adequate, then the scintillator should be checked.

Gain vs Voltage plots are found below, with the present nominal operating point circled in red (~5E6 gain near 1800V). The same model and data are plotted twice on different scales. The data are from Simona Malace and her team of students. They used the single photoelectron peak to measure the gain. They didn't go lower in voltage because the signal got too small, and they didn't go higher because they didn't know at that time the maximum rating of the base.

[1] The gain target is a soft number based on 100% efficient detection of a minimum ionizing signal from the far end of a paddle after the long cable run to the upstairs discriminator.

My program GvsV_version6.f was used to model the gain. Agreement between model and data is at the level of ~√2 which is excellent given the fact that these pmt's are not new, and the model is doing a lot of extrapolating from the manufacturer's resistive divider B to the actual zenerized base design.

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

- HMSHodoXP2262GainvsVoltageModel_longoutput.dat
- HMSHodoXP2262GainvsVoltageModel_shortoutput.dat,
- HMShodoGainVsVoltage.pdf,
- HMShodoGainVsVoltageZoomed.pdf
- HMShodoGainVsVoltage.xlsx,

Comments:

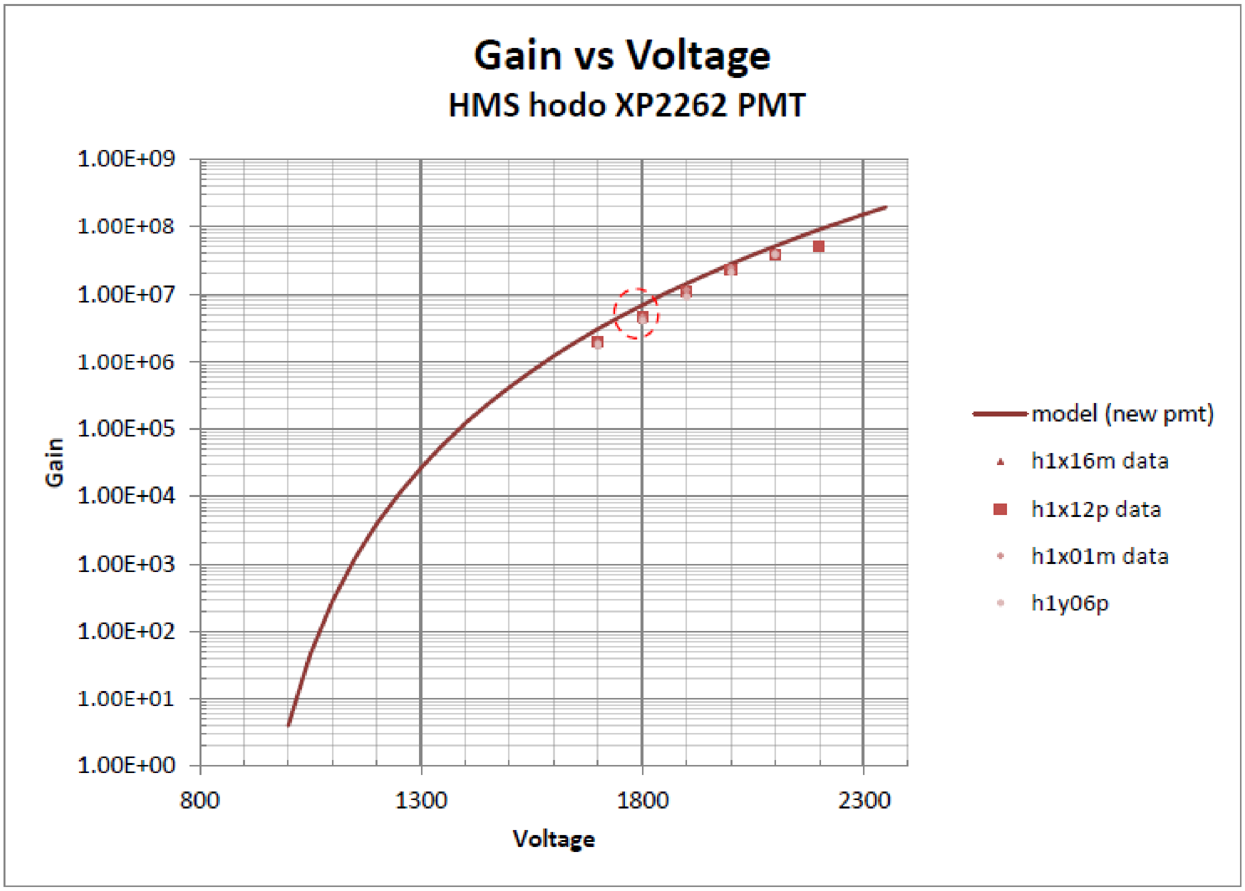
* Near 1800V, every additional 100V gets us a factor of 2 more gain. (For pmt's with fewer stages, one needs more than an extra 100V to get a factor of 2 increase in gain.)

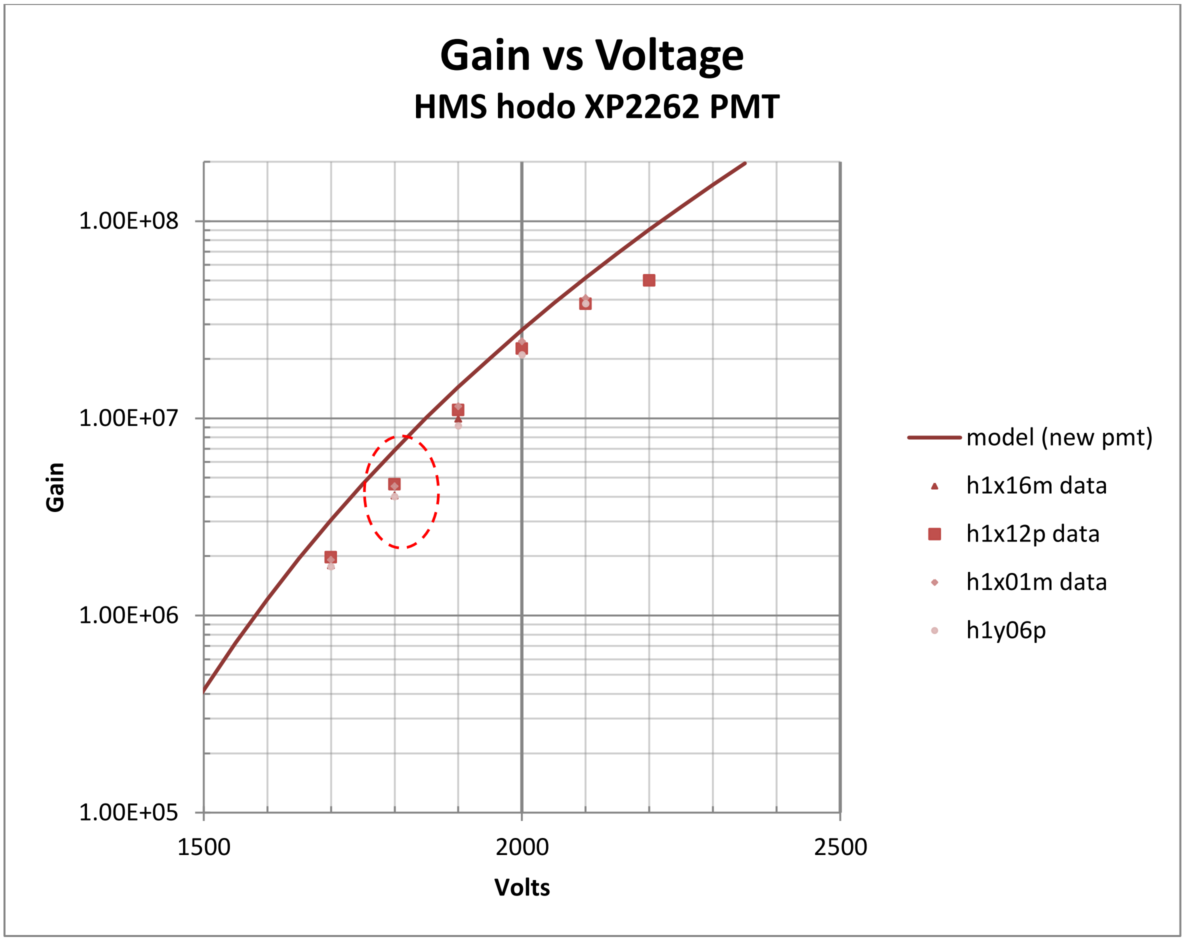
* Note that the strong curvature in the log(Gain) vs HV plot is due to the zeners. This base has ~900V worth of zeners. Below 1500V the gain starts diving for 0 faster and faster. But that hardly matters for us since the nominal operating voltage is much higher.

Methods:

My model 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 purely resistive, divider B curve. The base we are actually using is what I would call a "zenerized implementation of a type B-ish divider with one inconsequential mistake". (See table below with differences highlighted in red. There are more differences than there are similarities.) I think the inter-stage voltages delivered by this base are quite reasonable near our nominal 1800V, and the mechanical and electrical layout is superb. However, the actual divider and divider B are apples and oranges, so my model is doing a lot of extrapolating and the simple $g_i = \beta V_i^{\alpha}$ ansatz is being thoroughly tested.

Our base	307V	1.00R	1.33R	1.00R	1.00R	1.00R	1.00R	1.00R	1.00R	1.25R	151V	200V	248V
Divider B	4.0R	1.10R	0.90R	1.00R	1.00R	1.00R	1.25R	1.25R	1.50R	2.25R	1.75R	2.75R	2.5R


Gain vs Voltage
HMS hodo XP2262 PMT
Gain
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
800
1300
1800
2300
Voltage
model (new pmt)
h1x16m data
h1x12p data
h1x01m data
h1y06p


Gain vs Voltage
HMS hodo XP2262 PMT
1.00E+08
1.00E+07
1.00E+06
1.00E+05
Gain
1500
2000
2500
Volts
model (new pmt)
h1x16m data
h1x12p data
h1x01m data
h1y06p