Summary of PreShower XP3462+base Modelling

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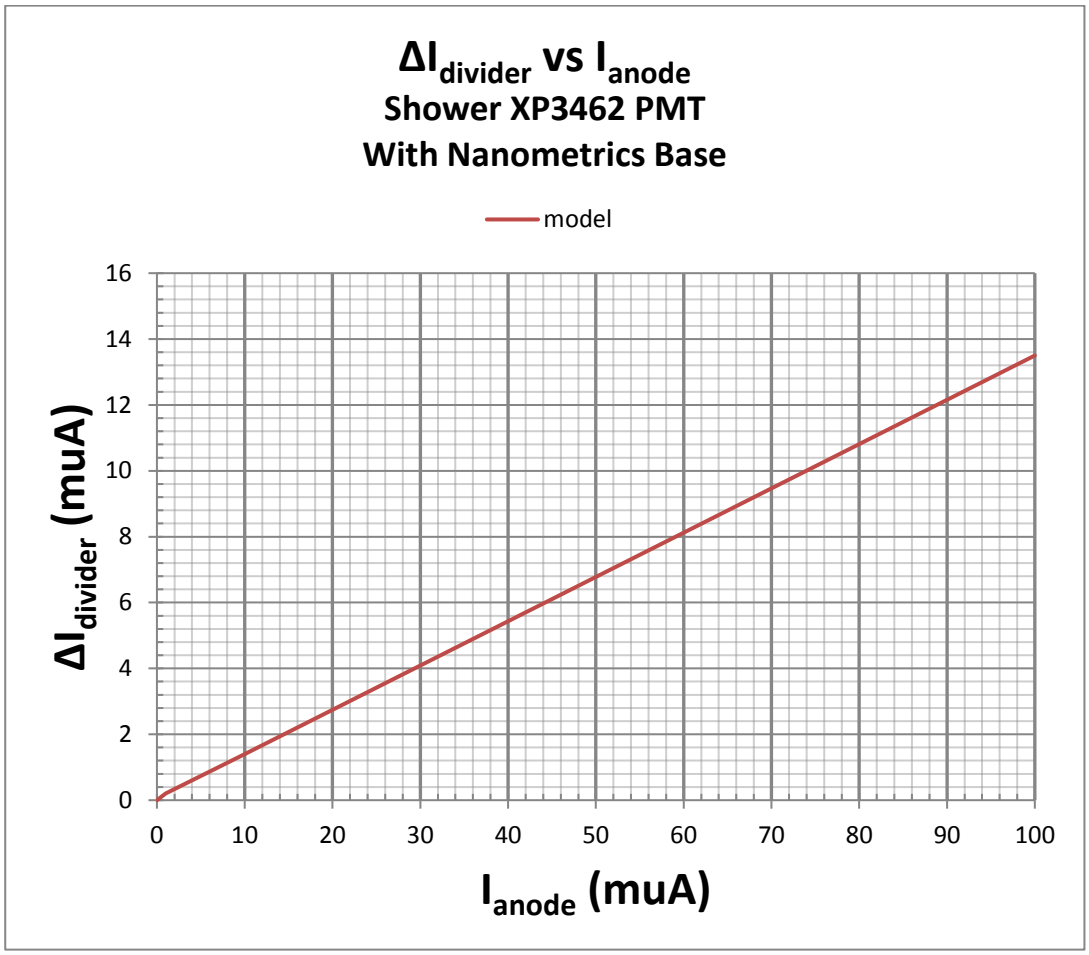
XP3462 pmts with Nanometrics bases have been used in the Hall C HMS calorimeter for decades. They are also now employed in the SHMS pre-shower detector. In addition to filling in gaps in our documentation for legacy detectors, my purpose in modelling this pmt-base combination now was to determine how the divider current subtly changes with increasing anode current. During March 2017 commissioning in Hall C we operated at fairly low luminosity (5 muA on 0.5% RL Carbon target) yet I saw small changes in the divider current that in a back of the envelope calculation suggested surprisingly large anode currents. (See HClog https://logbooks.jlab.org/entry/3467517 .) To make accurate estimates of the anode currents, the first step was to model the pmt-base combination with my program GvsV. I briefly summarize the results below.

Maximum HV: Unfortunately, this spec comes in two forms, hard and soft maximum limits. The hard maximum HV for the bases is about 1950V. Above that, one of the resistors between K and D1 (there are several due to two focusing grids) may burn up. Presumably by intelligent design, this is also the HVmax at which the divider reaches the 3mA maximum of our legacy CAEN HV mainframes. There is also a soft limit for the HV based on when the maximum gain of 3E6 is exceeded at which point some tubes may begin to feed back. For new pmts, this is predicted to occur around 1800V. Since the pmts used in the SHMS pre-shower are re-purposed tubes from the SOS, a higher voltage will be needed on average to exceed the maximum gain spec.

Gain Reserve: These are 8-stage pmts, so one only gets about a factor of x1.6 in gain per additional 100V near the operating point of 1500V. From the gain vs voltage plot below, assuming the nominal HV is 1500V and a practical maximum is 1900V, then there is about a factor of 5.5 gain in reserve. That is somewhat more than two half-lives. That's not a lot, but it should be enough if we keep the anode currents low during the 12 GeV operations.

Speaking of keeping anode currents low, my model was designed to study gain changes with increasing anode current, but it can also be used to study how the divider current changes. By running GvsV for 0, 1, 10, and 100 muA, I find the divider current changes 13.5 muA per 100 muA change in anode current. (See plot below) To put this number in context, the divider current is 2.3mA, so these changes are much less than 1%. **The dimensionless "base regulation parameter" is dI_{div}/dI_{anode} = 0.135 .** (It was expected from a back of the envelope estimate that

it would be O(0.1), meaning that a small change in divider current would imply an order of magnitude larger change in anode current. I will use the more accurate value for estimating the anode current in a followup in the HClog to https://logbooks.jlab.org/entry/3467517 .)



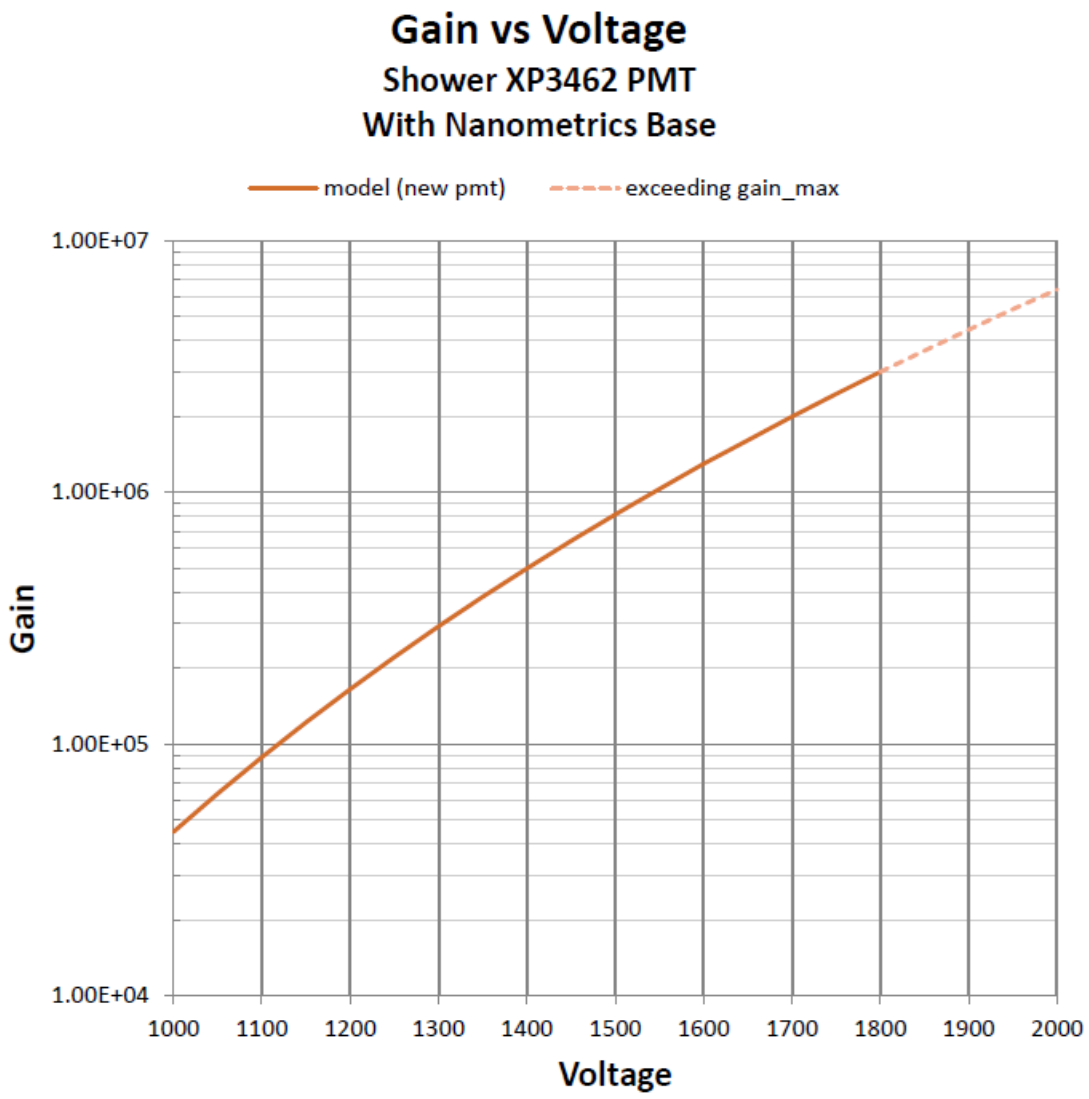
The output files contained in this same Hall C docDB entry are

- ShowerXP3462GainvsVoltageModel_longoutput.dat
- ShowerXP3462GainvsVoltageModel_shortoutput.dat
- ShowerGainvsVoltageModel.pdf (see plot at the end of this document)
- ShowerXP3462GainvsVoltage.xlsx

Methods:

My program GvsV_version6.f was used to model the gain and power dissipations. It assumes the gain for each active stage is given by $g_i = \beta V_i^{\alpha}$. With some tedious algebra, I extracted the two parameters α and β from the manufacturer's curve for the Divider B. The base we are using was built by Nanometrics. If we ever had a formal schematic in a drawer somewhere, it was lost when Vulcan retired. The Yerevan NIM article has the resistance values, but not the power ratings, so Hamlet and I had to half-guess that the resistors were rated for 1 Watt. Because linearity was an important specification for the calorimeter, the base design is Divider B-ish. (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-anode
Nano-metrics base	3.93R	1.89R	1.25R	1.25R	1.25R	1.25R	1.56R	2.5R	1.89R
Divider B	3.12R	1.5R	1.25R	1.25R	1.5R	1.75R	2R	2.75R	2.75R


Gain vs Voltage
Shower XP3462 PMT
With Nanometrics Base
model (new pmt)
exceeding gain_max
1.00E+07
1.00E+06
1.00E+05
1.00E+04
Gain
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Voltage