SiPM Notes:

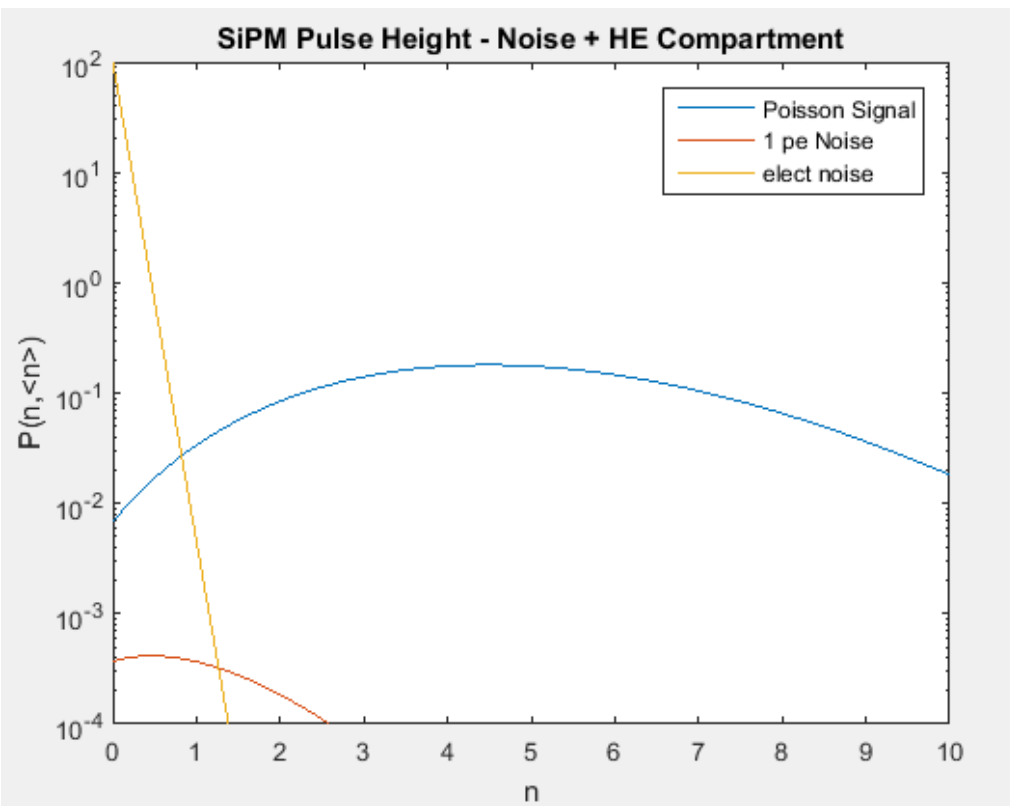
A simple model of the SiPM signal:

Suppose the mip in a longitudinal compartment has a mean # of pe, <n>. The Poisson distribution is quantized, but the effects of noise smearing can be simulated by using the gamma function to interpolate between integer n values. The probability, P, is ~ normalized to 1.

$$P(n,<n>) = [<n>^{n}\ e^{-<n>}]/\Gamma(n+1)$$

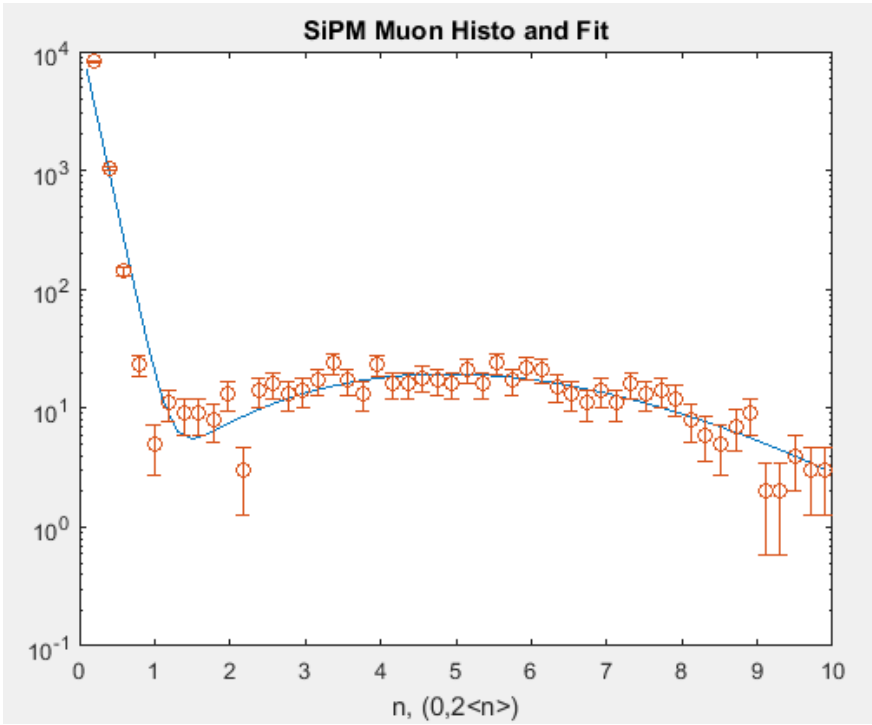
A possible simple model has 3 sources. First the actual mip signal from muons. Second the ~ exponential electronic noise, defined to be $R_n[b_n e^{-b_n n}]$ with a total integrated rate R and a slope b. Third, the 1 pe "cathode" or light leak noise. The plot below has a 5 pe <n> signal, a front end noise 50 times larger (in the sense of noise slope, b = 10, times <n>) with a slope of 10 1/pe and a rate (area) R of 10 compared to the signal area which was normalized to 1.

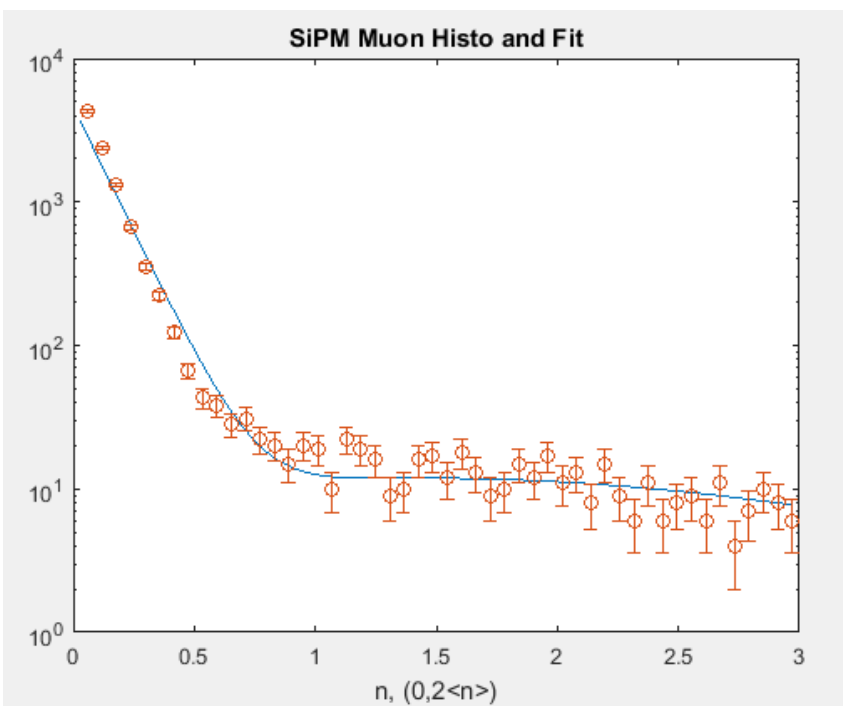
There is also a 1 pe noise of 0.1% of the mip rate. There are probably enough parameters in this model to characterize the SiPM output. Darkening can be simulated by reducing the signal p.e. with respect to the electronic noise. Increased noise can be added by having the electronic rate increased or by having the 1 pe noise increased. A fit can then be made in order to track and extract the mip muon signal..



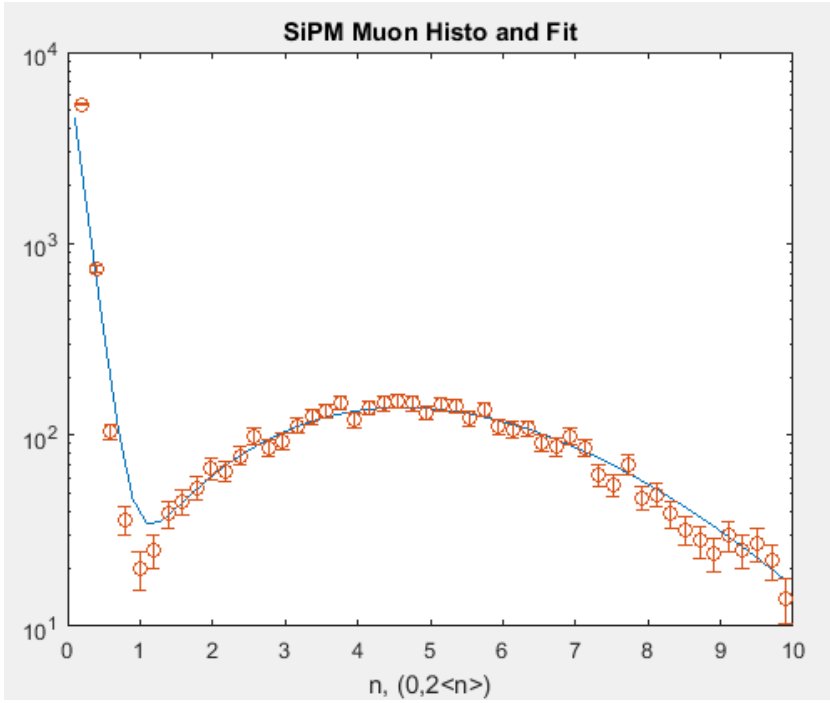
A fit is made to a histogram of the pulse height. There are 50 bins going from n=0 to n = 2<n>. The fits allows the normalized generated signal to float, <n> to float, the 1 pe noise rate to float and the electronic noise rate and slope to float. The result of a fit to the model above with 10^4 events appears

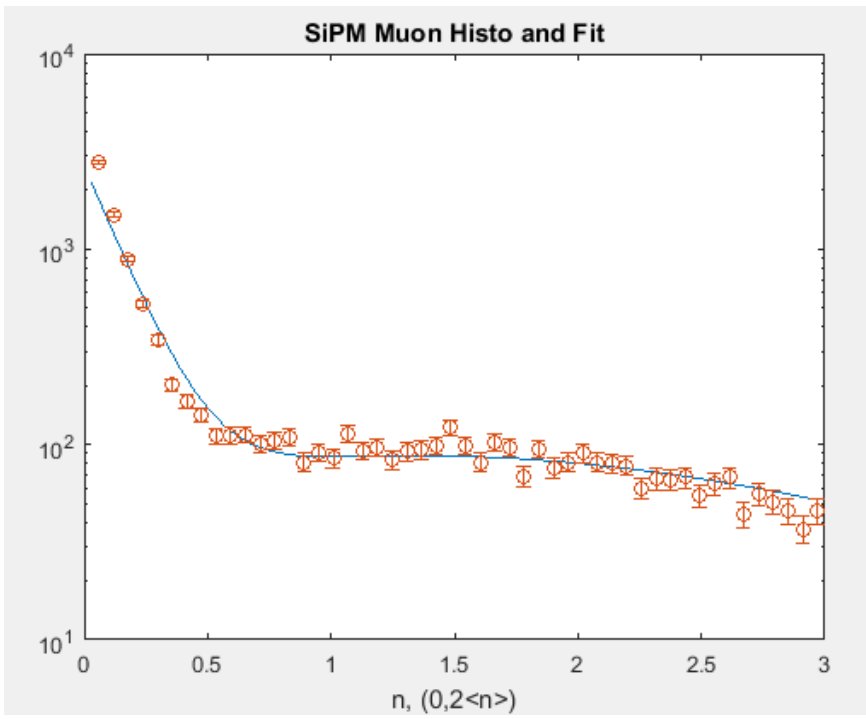
below. The second fit is for a mean pulse height of 1.5 pe. In that case the lower part of the signal spectrum is being engulfed by the assumed noise spectrum which systematically increases the best fit <n> value.





The effect of darkening can be seen from the above spectra and the associated fits. If the noise rate at fixed exponential slope is 10 times less, the fits are more robust, as expected. The 2 plots below are for <n> = 5 and <n> = 1.5 in that case. For <n> = 5 a nice S/N separation is observed.


SiPM Muon Histo and Fit
10^4
10^3
10^2
10^1
0
1
2
3
4
5
6
7
8
9
10
n, (0,2<n>)


SiPM Muon Histo and Fit
10^4
10^3
10^2
10^1
0
0.5
1
1.5
2
2.5
3
n, (0,2<n>)

The calibration using mip degrades as the # of pe decreases as seen below from the fits made.

Noise rate	10	10	1	1
<n> 5	5.23	0.12	5.08	0.055
4	4.13	0.14	4.06	0.06
3	3.22	0.26	3.13	0.10.
2	2.29	0.37	2.17	0.22
1.5	2.04	0.8	1.8	0.51

The errors increase with decreasing <n> and with increasing noise rate (S/N for <n> = 5 is fixed at 50 w.r.t. <n> / noise width). There is a systematic shift in the fitted <n> due to the noise.

The model needs more realistic input from test beam data taken already.