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OPTICAL MODULE SIMULATION

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This is a short note to simply document how the response of the Optical Modules (OMs) is currently simulated in the Hawaii DUMAND Monte Carlo Program DUMC. This should serve to not only provide information on the Monte Carlo, but to illustrate the type of information that will be needed from OM calibration measurements and ultimately included in the data analysis software.

Given an incident photon flux ϕ photons/m^2, from a single muon track, multiple muon tracks, and/or hadronic or em cascade, already corrected for losses in the ocean, hard hat, Benthos and PMT glass, and gel, the average pe is taken as:

$$<n> = S\ \phi\ f(\psi)$$

where S is the PMT peak sensitivity, given by

$$S = \eta\ \phi\ r^2 = 0.0023 \text{ pe m}^2$$

where η is the peak quantum efficiency and $f(\psi)$ is the angular response function:

$$f(\psi) = .525 + .475 \cos\psi$$

for the Hamamatsu tube, and

$$\begin{aligned} f(\psi) &= .546 + .606 \cos\psi && -.9 < \cos\psi < .75 \\ &= 1 && \cos\psi > .75 \\ &= 0 && -.9 < \cos\psi \end{aligned}$$

for the Philips tube, where ψ is the polar angle of the light incident on the tube.

NOTE: The Philips parameters were provided by the Baikal group. They need to be measured for the DUMAND Philips module.

The true number of pe is then simulated as

$$n = P(<n>) \quad \text{for } n < 50, \quad n = <n> \text{ for } n >= 50$$

where $P(<n>)$ is a Poisson-distributed variable with mean $<n>$.

For random background, $n = 1$ and $f = 1$. The trigger rate is an external parameter.

The true no. of pe, n, is then smeared to a floating point value q as follows.

For the Philips tube,

$$q = (x - C_2)/C_1$$

where

$$x = G(\langle x\rangle, \sigma)$$

is a Gaussian–distributed variable of mean $\langle x\rangle$ and standard deviation σ, where

$$\langle x\rangle = C_1 n + C_2$$

where $C_1 = 98.1$, $C_2 = 68.9$ (as typical values) and

$$\sigma = \sqrt{n}\, \sigma_1$$

where $\sigma_1 = 30$.

For the Hamamatsu tube,

$$q = G(n, \sigma_n)$$

where $\sigma_n = \sqrt{(n+1)}$.

In both cases, the voltage input to the discriminator is assumed to be proportional to q. The current trigger is $q = 1/3$ pe.

The value of q is used for the trigger. However, in track fitting a simulated q must be obtained from inverting the above expressions relating q and pulse width, since this is the information that will be available on shore. I will not present the expressions currently used for pulse width since they are obsolete and need to be replaced by more realistic expressions. The OM builders are asked to soon provide information on how the pulse widths will be generated and provide an estimate of what the error distribution is for q determined by pulse width.