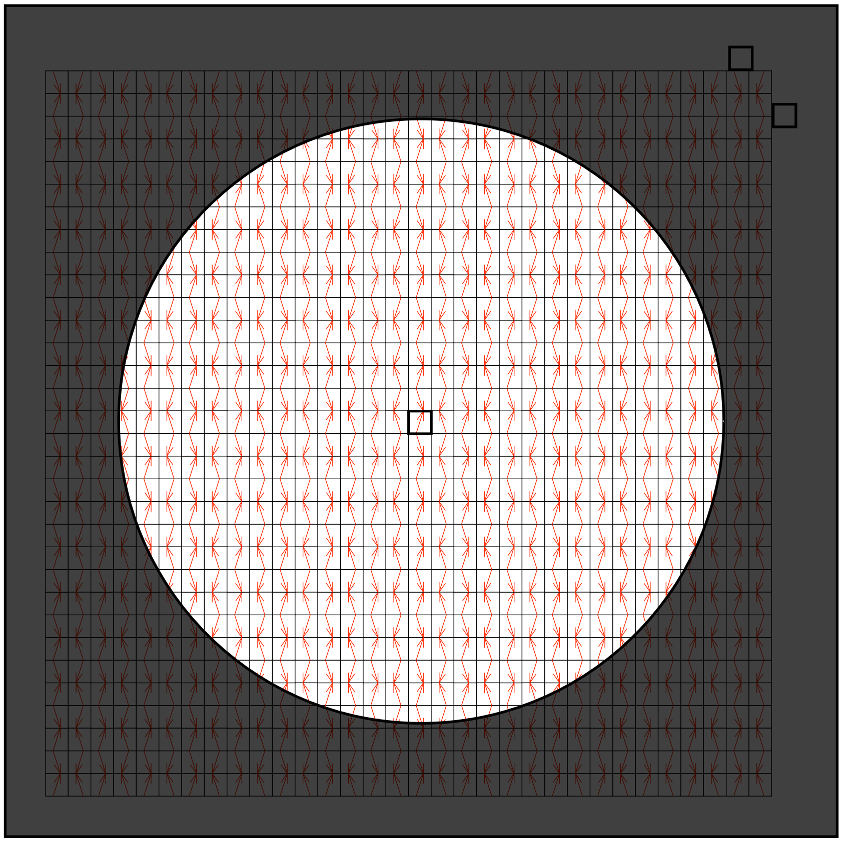
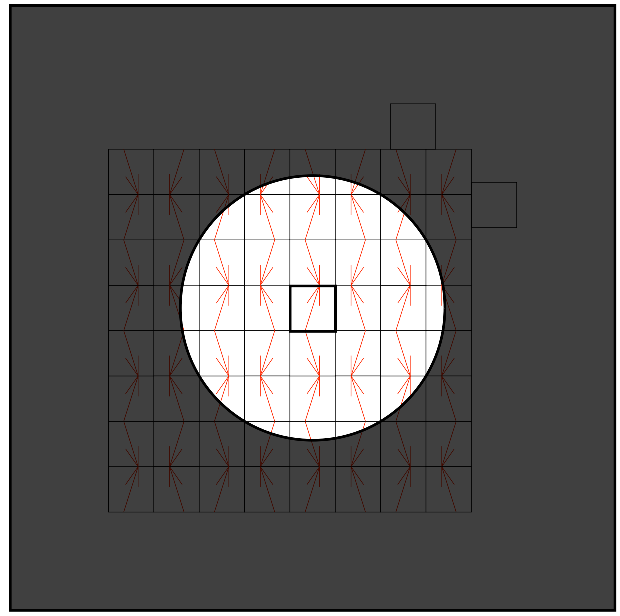
"View" from the PMT

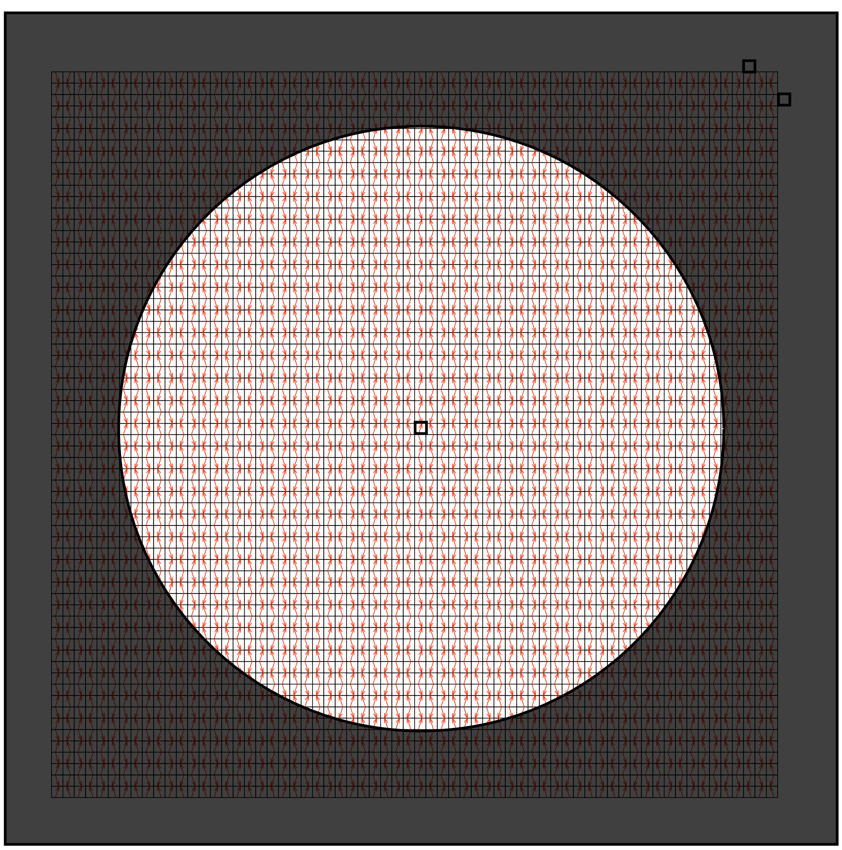
Track in 5 cm bar at 1.5 m from PMT.



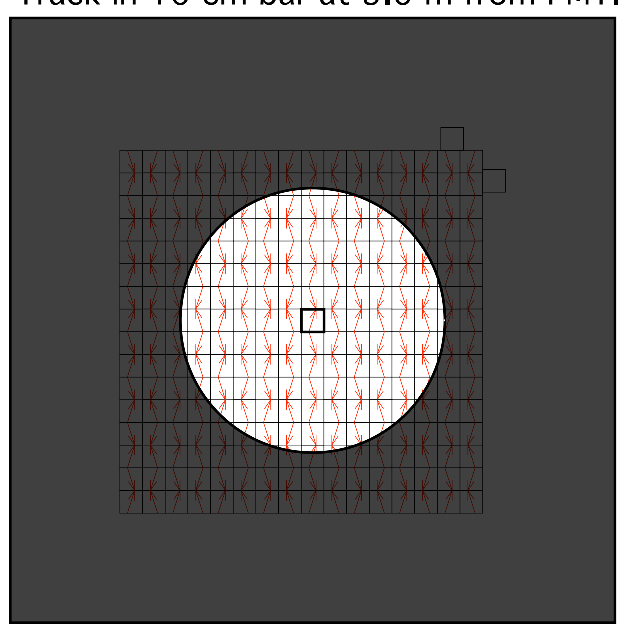
Track in 10 cm bar at 1.5 m from PMT.



Track in 5 cm bar at 3.0 m from PMT.



Track in 10 cm bar at 3.0 m from PMT.

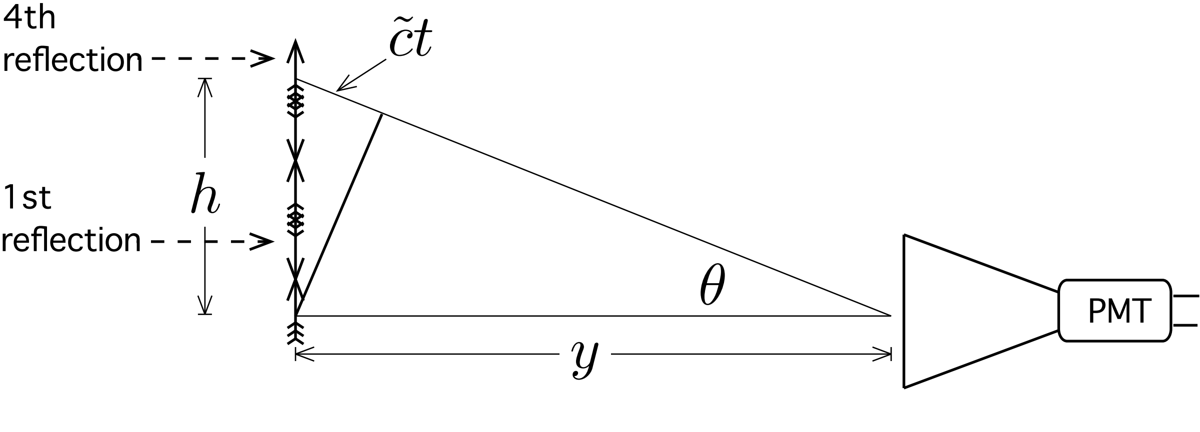


The Leading Edge of TOF PMT Pulses

- Consider the following model of the leading edge of the PMT's output pulse.

  - a) The charged particle deposits energy in the scintillator bar instantaneously. In reality this process occurs uniformly over an interval of 150 ps in 5 cm bars or 300 ps in 10 cm bars.
  - b) The scintillation light is produced instantaneously at the time of passage of the charged particle. In reality this process occurs with a risetime of about 500 ps. (The scintillator manufacturers quote a rise time of 0.9 ns, but they have not defined "risetime.")
  - c) Each photoelectron that leaves the photocathode produces an anode pulse with a leading edge $dV/dt = \sigma$.

- The following figure shows that even under the favorable assumptions above, the photons from a track do not arrive at the photocathode isochronously. As time advances, photons at increasing angle with respect to the optical axis reach the PMT.



$$
\begin{aligned}
\theta &< 0.42 \\
(\sin(0.42) - 0.42)/0.42 &\simeq 0.03 \\
h &\simeq y\theta \\
\tilde{c}t &\simeq h\theta, \quad \tilde{c}/c = 1/1.58 \\
\frac{\tilde{c}t}{y} &\simeq \theta^2
\end{aligned}
$$

- Each reflection from a vertical surface of the bar (but shown horizontal in the above figure) preserves the magnitude of the angle with respect to the optical axis. Let $n(t)$ be the number of photoelectrons produced prior to time t with $t = 0$ being the time of arrival of a photon with $\theta = 0$. Then

$$
\begin{aligned}
n(t) &\propto \pi h^2 \\
&\propto \pi y^2 \theta(t)^2 \\
&= \pi N_c y^2 (\theta(t)^2/\theta_c^2) \\
&= \frac{\pi N_c}{\theta_c^2} y^2 \theta(t)^2 \\
&= \frac{\pi N_c}{\theta_c^2} y^2 \left(\frac{\tilde{c}t}{y}\right) \\
&= \frac{\pi N_c \tilde{c}}{\theta_c^2} yt
\end{aligned}
$$

- In conformance with assumption c) above each photoelectron emission contributes σ to the dV/dt of the anode pulse:

$$
\begin{aligned}
dV/dt &= \sigma n(t) \\
&= \frac{\pi N_c \tilde{c} \sigma}{\theta_c^2} yt
\end{aligned}
$$

- and thus

$$
V(t) = \frac{\pi N_c \tilde{c} \sigma}{2\theta_c^2} yt^2
$$

- Let V_D be the threshold of the discriminator and let t_D be the time at which the discriminator triggers on the PMT pulse. Then

$$t_D = \theta_c \left(\frac{2V_D}{\pi N_c \tilde{c} \sigma} \right)^{1/2} y^{1/2}$$

- We also have Q, the output from the ADC. What does Q measure? Because the ADC integrates over the entire PMT pulse, Q measures N_c, $Q = gN_c$. Then

$$\begin{aligned} t_D &= \theta_c \left(\frac{2gV_D}{\pi \tilde{c} \sigma} \right)^{1/2} \frac{y^{1/2}}{Q^{1/2}} \\ &= A \frac{y^{1/2}}{Q^{1/2}} \end{aligned}$$

  where A is a "universal" constant, i.e. independent of the scintillator bar or PMT.

- I have considered alternative, more realistic models than the one specified at the outset. The effect of introducing delay in the photon emission is to increase the power of the t dependence of V(t).

$$\begin{aligned} V(t) &= Byt^{\beta} \\ t_D &= A \frac{y^{1/\beta}}{Q^{1/\beta}} \end{aligned}$$

- where β rises to 3 or maybe 4, and as before A is universal for bars of a given geometry. (We do not expect A for the 10 cm bars to be the same as for the 5 cm bars.) In every case the exponents of y and of Q are the same.

- This analysis suggests the following strategy for calibrating the TOF wall.
  - Using beam tracks in the central four bars, adjust A and β to minimize the width of the distribution of $TDC - t0 - t_D$. Expect to find a trough in the A, β space with a poorly determined minimum.
  - Using clean secondary tracks in a larger selection of 5 cm bars, plot $t_{top} - t_{bot}$ vs y. Then slide A, β along the trough until the slope of this plot is $\tilde{c}$.
  - Use the A, β pair determined by this strategy to refine the time/temperature dependent offsets. For 5 cm bars these offsets are the only PMT dependent calibration "constants." Note that a constraint on the offsets is that the plot of $t_{top} - t_{bot}$ vs y should pass through the point $t_{top} - t_{bot} = 0$, $y = y_{center}$.