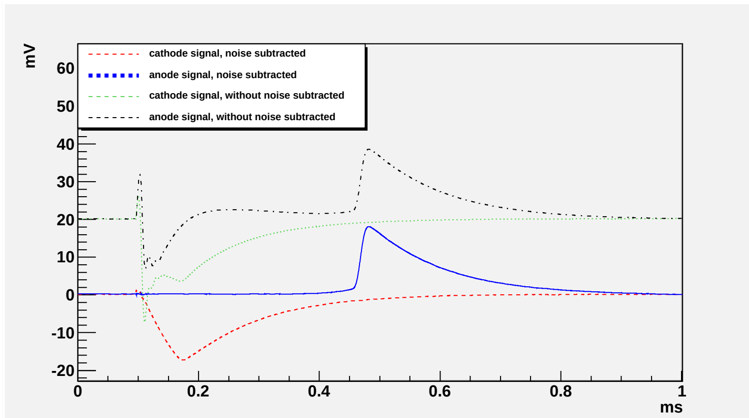


Figure 1:

This note contains a detailed description of how the numbers Q_a and Q_c are extracted from the purity monitor traces. While this description is much to detailed for the NIM paper currently being written, it is a useful reference for anyone commenting on the paper that does not have access to the C++ code used for the calculation.

Figure 1 shows the smoothed traces recorded by the purity monitor DAQ program that are used to obtain the reported values of Q_a and Q_c. After smoothing, the signal traces are obtained by subtracting the measured noise trace, with purity monitor electric field off, from the measured traces with the electric field on. The subtraction is done by subtracting the arrays that constitute the digital record of the waveforms. The short purity monitors waveforms were digitized at 5000000 samples per second with 500 samples before the trigger that defines $t = 0$.

The maximum pulse height of these traces, $V_{max,a}$ and $V_{max,c}$, are identified for each waveform as the maximum number in the array of numbers that stores the noise-subtracted digitized waveform. The charge seen by the cathode (anode) is then calcuated as $Q = (V_{max} - V_0) * f(\Delta t, RC)$, where V_0 is the measured baseline for the trace and $f(t_{pulse})$ is a correction for the electronics response function that depends on the time duration of the current pulse, Δt and the measured RC time constant of the electronics.

In the case of the cathode, V_0 is calcuated as the average of the 50 values in the 10 μs window centered around $t = 0$. For the anode, V_0 is the average of the 100 values in 20 μs wide window whose center is earlier than the anode peak time by one third of the time difference between the anode and cathode peaks.

The correction for the electronics response is derived from the simplified circuit shown in figure 2, assuming that the input current $I(t)$ is a square pulse with height I_p and time duration Δt.

$$f(\Delta t, RC) = \frac{Q}{V_{max} - V_0} = \frac{\Delta t}{RC} \frac{1}{1 - \exp(-\frac{\Delta t}{RC})} \tag{1}$$

For the cathode pulse, $\Delta t = t_{cath} + 6$ μs where t_{cath} is the time from the trigger at $t = 0$ to the time of the peak of the cathode pulse. For the anode pulse, a linear rise is assumed for $V(t)$. The waveform times corresponding to $V(t) = 0.25 \cdot V_{max}$ and $V(t) = 0.75 \cdot V_{max}$ are used to determine m, the slope of the rise, and $\Delta t = V_{max}/m + 5$ μs. I don't know how the 5 and 6 μs additions were determined (but Stephen should). The value of $RC = 119$ μs is used for all PrM anode and cathode signals. For standard LAPD run-2 running conditions for purity monitor 4, the correction for the cathode pulse height is $f = 1.38$ and the anode pulse height is $f = 1.09$.

Fits to the tail of the measured waveform give values in the range 119-132 μs. We note that higher values of RC decrease the value of f for the cathode pulse, and thus the value of Q_c while Q_a is not affected. The values of $\frac{Q_a}{Q_c}$ determined with the lower limit of the RC values, are thus lower limits themselves. This allows us to quote a lower limit to the measured electron lifetime.

The ratio g^α/g^β corrects for small gain variations among the channels of the amplifiers, and was measured by swapping channels for the anode and cathode signals of the same purity monitor and noting the change in the ratio $Q_{anode}/Q_{cathode}$. This measured ratio could depend on the operating voltages of the anode, cathode, anode grid and cathode grid, especially if the f correction factors are only approximate. For purity monitor 4, $g^\alpha/g^\beta = 0.973$

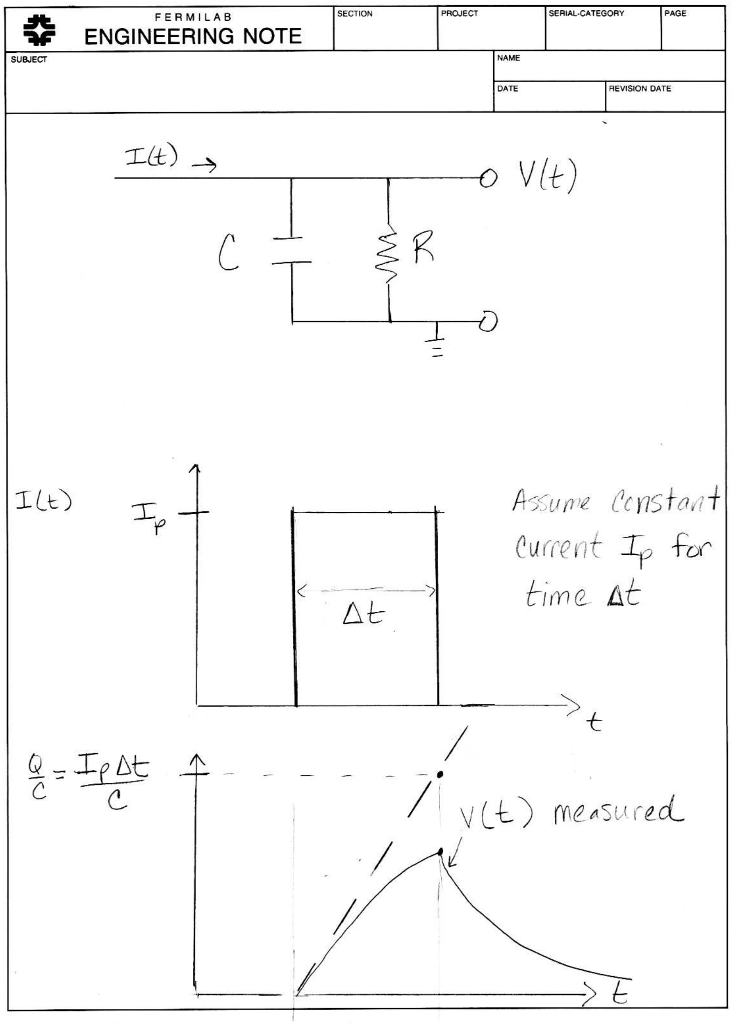
In the PrM code, the lifetime is calculated as

$$\tau = \frac{t_{drift}}{\ln((g^\alpha/g^\beta)(Q_{cathode}/Q_{anode}))} \tag{2}$$

where $t_{drift} = t_{anode}(= 0.3813)$ is the time from the trigger ($t = 0$) to the peak of the anode pulse. There were discussions about whether the quantity $t_{drift} = t_{anode} - t_{cathode}(= 0.3068)$ is more appropriate. This is the time of the peak of the anode pulse minus the time of the peak of cathode pulse. In the interest of presenting the systematic uncertainties as all things that increase the measured value of $\frac{Q_a}{Q_c}$, I propose to use the second, smaller value of t_{drift} as it gives a smaller value of the lifetime. The disadvantage to this choice is the second systematic error discussed below.

There are three sources of systematic uncertainty that could be significant. For each of these quantities, limits were used to determine a lower limit for $\frac{Q_a}{Q_c}$, so that a lower limit on the electron lifetime can be quoted.

The first is the acceptance of the anode, which we assume to be 100%. It is different from 100% if any electrons generated at the cathode traverse the entire drift distance without encountering and impurity, but are not counted at the anode because they traveled too far transversely from the axis of the purity monitor. The second is the possibility that electrons generated at the cathode induce a signal on the cathode grid, and are thus counted in Q_c, but


FERMILAB
ENGINEERING NOTE
SECTION
PROJECT
SERIAL-CATEGORY
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SUBJECT
NAME
DATE
REVISION DATE
I(t)
V(t)
C
R
I(t)
I_p
Assume Constant
Current I_p for
time Δt
Δt
t
$\frac{Q}{C} = \frac{I_p \Delta t}{C}$
V(t) measured
t

Figure 2:

were actually absorbed by an impurity before arriving at the cathode grid. We assume that this does not happen, and thus the value of Q_c used is an upper limit and the lifetime derived from it is a lower limit. The third is the uncertainty on the RC time constant used to correct for the electronics response, as discussed previously. If any of these quantities is different than assumed, then the actual values of $\frac{Q_a}{Q_c}$ and the electon lifetime are larger than quoted.