Correction for the Non-Poissonian Bias in the EDTM Total Livetime for non-Buffered Mode

D. Mack

1/11/19

Updated 9/20/19

One Slide Summary – True Total Live Time in Unbuffered Mode

- Cut your data to production currents (to minimize the “clock bias” during beam ramps which Mark J pointed out).
- Determine EDTM nominal total live time as Eric P discusses in https://hallcweb.jlab.org/doc-private/ShowDocument?docid=1022 .
- The true total live time is approximately = EDTM nominal total live time * [1 – (Rp+Re)T + RpT { 1 + Re/(Rp+Re) }]

where Re is the nominal EDTM clock rate divided by the prescale factor (usually 100 Hz and not prescaled),

Rp is the rate of non-EDTM physics triggers in that arm (can be gotten from scalers, but EDTM events need to be subtracted), and

T is 250 musec. (The result is insensitive to +-10% variations in this parameter.)

- The electronic LT is therefore to an excellent approximation given by

$$\text{ELT} = \frac{\text{EDTM nominal total live time} * \left[\, 1 - (R_p+R_e)T + R_pT\, \{\, 1 + R_e/(R_p+R_e)\, \}\, \right]}{\text{Computer Live Time}}$$

I recommend first studying the systematics of the electronic LT to make sure it makes sense.
If it does, then unbuffered analyses may want to start using the true total live time.

The details ….

Motivation

Brad's EDTM initiative seeks to determine the total live time (ie, computer + electronic) needed for yield corrections.

By correcting for an independent determination of the computer livetime, this would allow us to infer the electronic live time in a manner which probes many of the relevant high rate nodes in the electronics.

The fact that the EDTM events are generated by a clock, rather than a Poissonian source, has some advantages. But the resulting EDTM LT is unfortunately biased a little too high to be appropriate for physics events (since a clock event cannot block a clock event). It needs correction before use.

Eric's plots at https://hallcweb.jlab.org/doc-private/ShowDocument?docid=1022 on EDTM LT – Computer LT suggested that 1st order corrections might be good enough to correct the EDTM livetime. Happy days! The derivation of the 1st order correction follows on the next slide.

Live Time Correction for Clocked EDTM Events in Unbuffered Mode

If Rp is the physics trigger rate, Re is the EDTM trigger rate, and T is the computer deadtim, then for our usual Poisson-distributed events the total detected rate to 1st order is

$$R_{tot}^{poisson} \sim (Rp + Re) - (Rp + Re)^2\, T = (Rp + Re)[1 - (Rp+Re)T]$$

where the term in brackets is the familiar 1st order live time, $LT^{poisson} = 1 - (Rp+Re)T$.

How is the live time different for <u>clocked</u> EDTM events? First, expand the original equation above into the seemingly unnecessarily complicated form

$$R_{tot} \sim (Rp + Re)\, [\, 1 - (RpRp + RpRe + ReRp + ReRe)T/(\, Rp+Re\,)\,]$$

Each of the Ri*Rj terms inside the brackets has a physical interpretation in terms of a contribution to the dead time, eg, Rp*Re is where an EDTM trigger arrived first and blocked a physics trigger, etc. For the clocked EDTM scenario, the only change we need to make is to <u>drop the Re*Re term because an EDTM event cannot block an EDTM event from generating a L1 Accept *</u>. We can then identify $LT^{clocked}$ as

$$LT^{clocked} = 1 - (Rp^2 + 2RpRe)T/(\, Rp+Re\,) = 1 - RpT\, \{\, 1 + Re/(Rp+Re)\, \}$$

You can confirm the latter expression has the expected limits by 1) setting Rp = 0 for nearly arbitrary Re, and 2) setting Re = 0 for arbitrary nearly Rp, etc. The true total LT to 1st order is therefore

$$\text{True Total Live Time} = LT_{EDTM}^{uncorrected} * (\, LT^{poisson}/LT^{clocked}\,)$$

Cont'd on next slide

*The EDTM rate is usually at least several orders of magnitude smaller than the detector rates, so any clock bias on the electronic LT must be negligible. Only the clock bias on the computer LT is being removed here.

Cont'd: Live Time Correction for Clocked EDTM Events in Unbuffered Mode

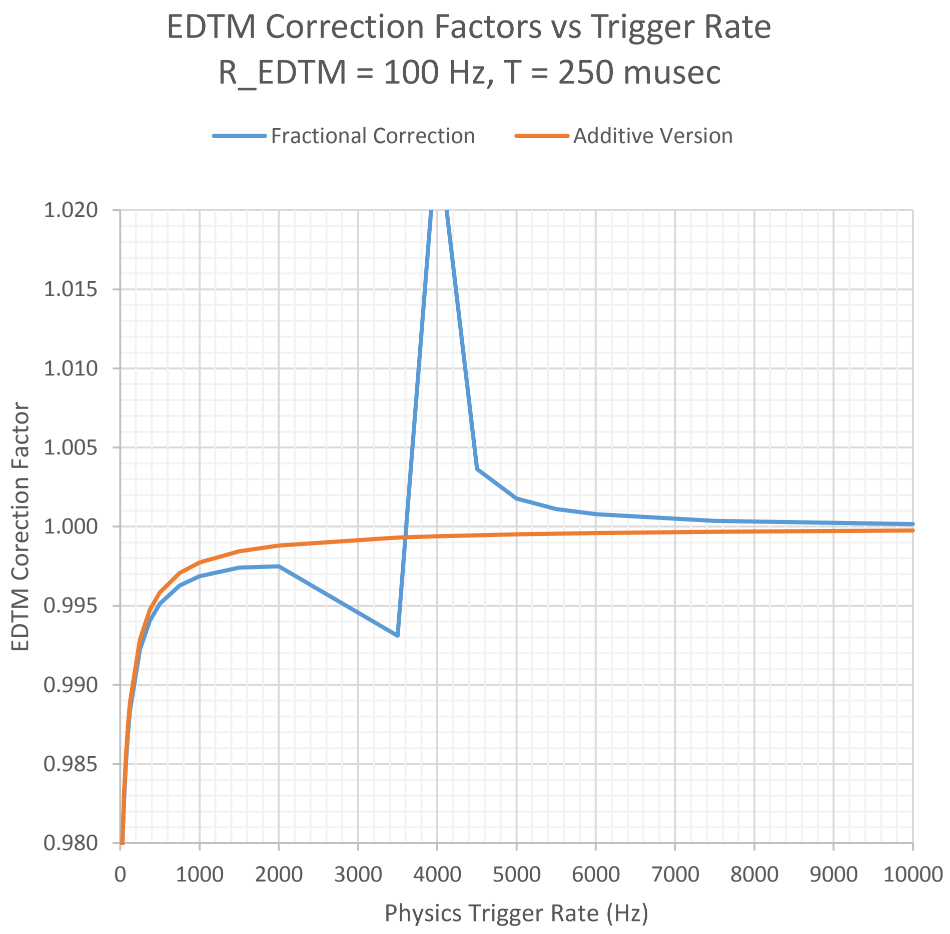
From the previous slide

$$\text{True total live time} = \text{EDTM nominal total live time} * \frac{1 - (Rp+Re)T}{1 - RpT\,\{\,1 + Re/(Rp+Re)\,\}}$$

In the example on the right, we can see the 1st order correction (blue curve) is well behaved below 1 KHz, and as large as 2%!

But the 1st order expression not surprisingly runs into trouble at higher rates where the denominator can vanish. This higher rate regime isn't very interesting since the EDTM clock bias is highly diluted so corrections should be at the O(0.1)% level. We just need a smooth way to interpolate to 1.000 .

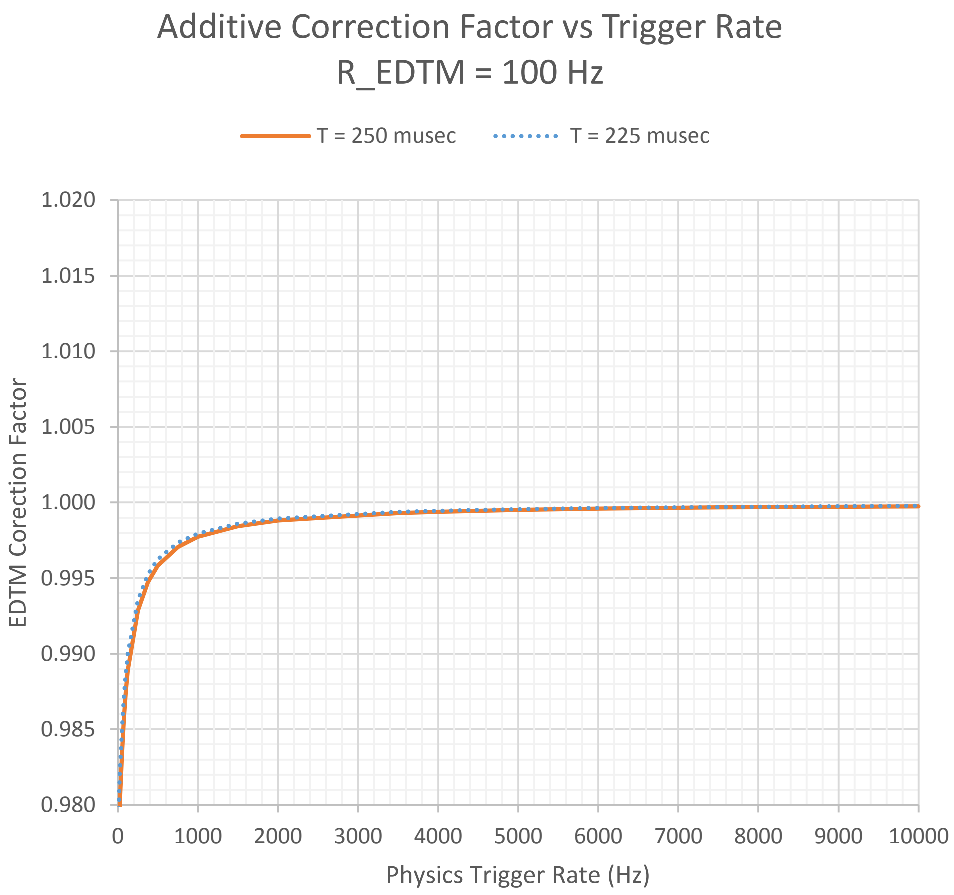
The Taylor series expansion of the above fortuitously turns out to be more stable (orange curve on right):

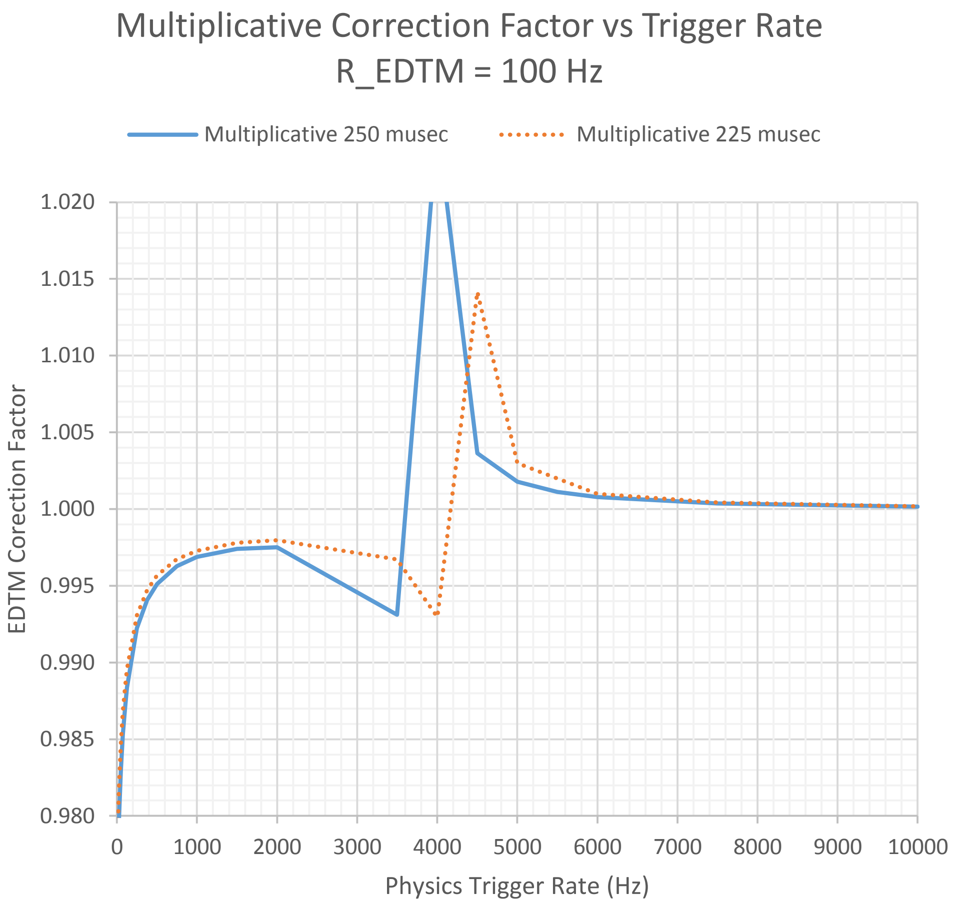


$$\text{True total live time} = \text{EDTM nominal total live time} * \left[\, 1 - (Rp+Re)T + RpT\,\{\,1 + Re/(Rp+Re)\,\}\,\right]$$

Cont'd: Live Time Correction for Clocked EDTM Events in Unbuffered Mode

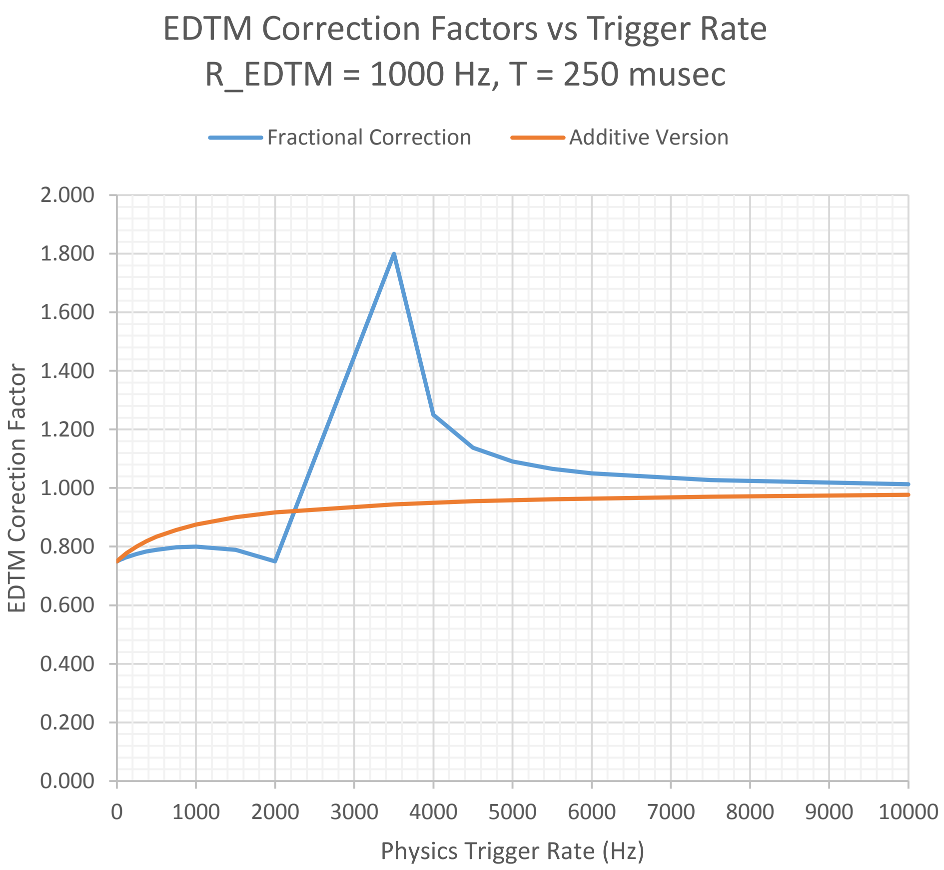
The additive correction (left) is also much less sensitive to the time the computer is dead while reading an event.

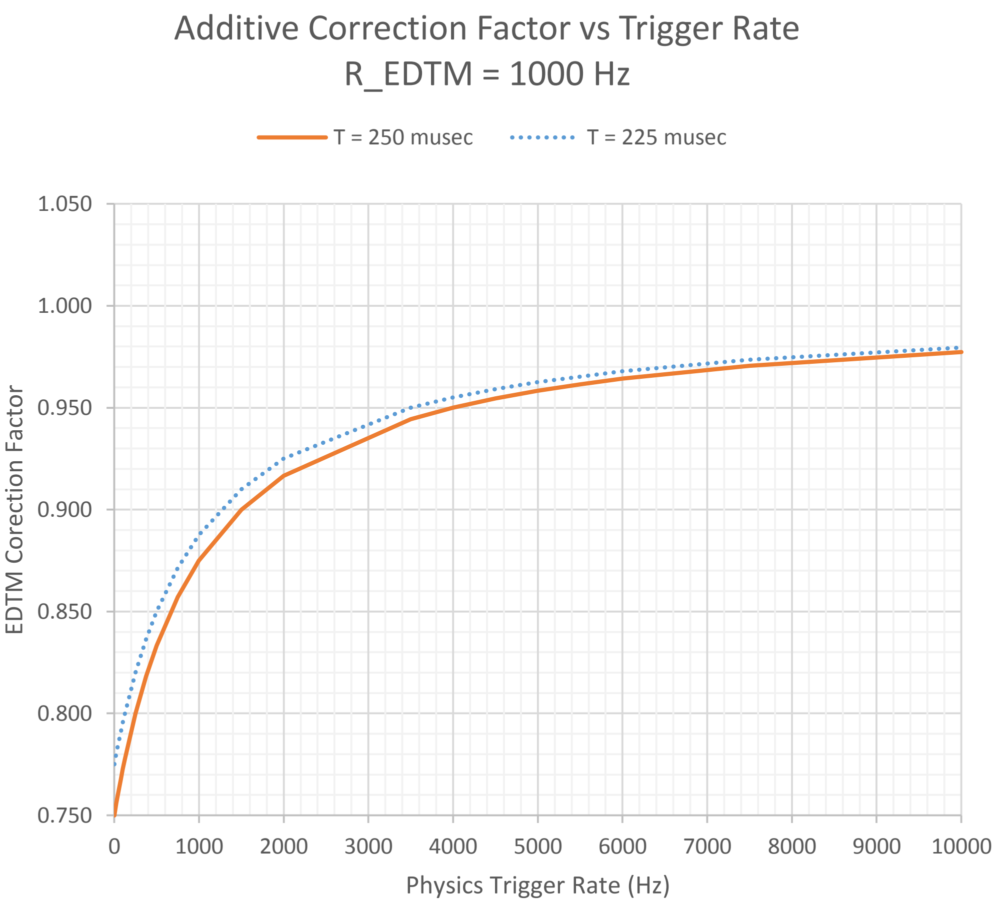




What happens if the EDTM rate goes to 1000 Hz?

The bias on the uncorrected EDTM nominal total live time gets big. And it stays big since 1KHz is a significant fraction of the unbuffered daq rate which we usually like to keep to less than a few kHz.

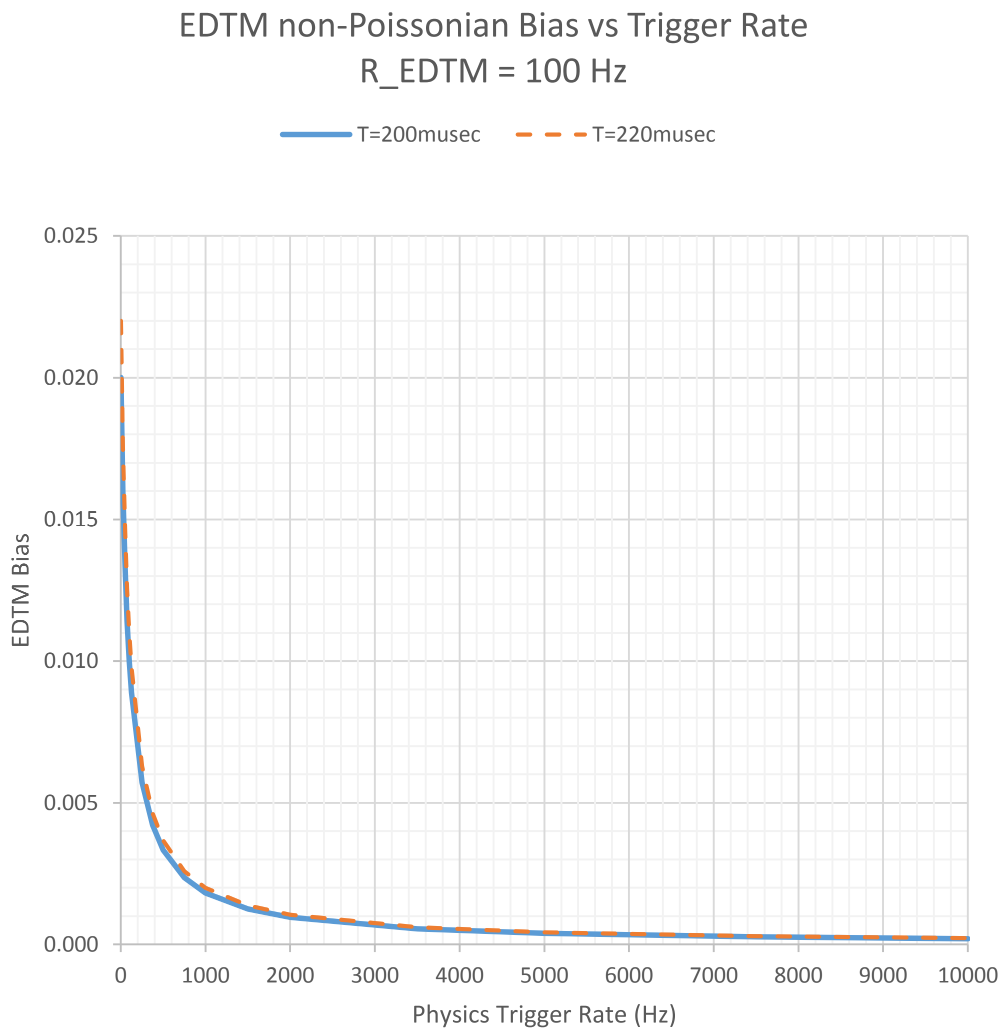


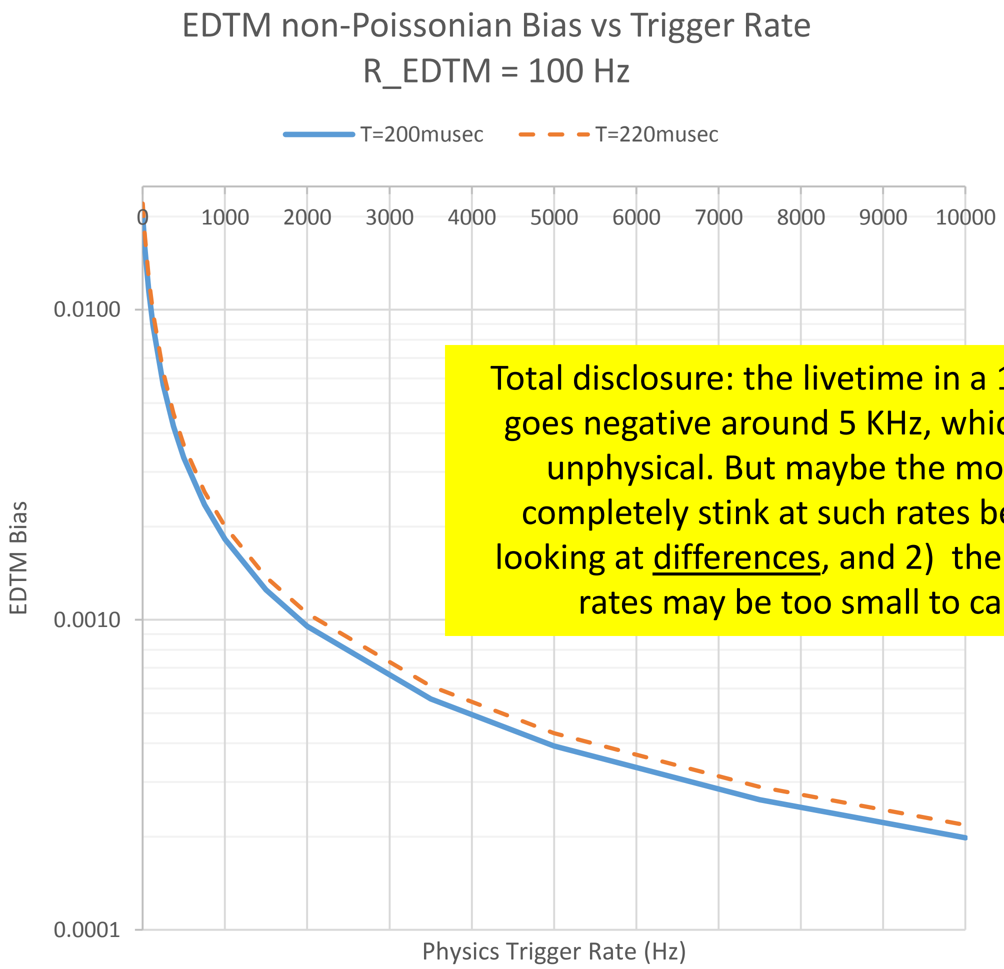


Backups

The almost apples to apples comparison should be wrt Eric's green triangles "EDTM Live Time – Computer Live Time (No EDTM)".

- These curves are semi-quantitatively similar to Eric's recent plots for the HMS. His SHMS data have larger uncertainties.
- I'm not sure it's relevant here, but for very high detector rates, remember that Eric's green triangles measure the bias - the electronic DT.





Total disclosure: the livetime in a 1st order model goes negative around 5 KHz, which is obviously unphysical. But maybe the model doesn't completely stink at such rates because 1) I'm looking at differences, and 2) the effects at high rates may be too small to care about.

Note how, above 1 KHz, the non-Poissonian bias is negligible (unless you're doing a lumi scan).

Zooming in on the low rate region, you can see why Eric could infer an uncorrected EDTM electronic live time of 102%.

It looks like there is enough model dependence on this correction to be a visible source of excess noise in a lumi scan. We'll have to tune the effective average deadtime parameter, T.