MICE timing and RF phase measurement

Parallel Session

CM33

Glasgow 25th – 29th June 2012

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Contents

Some of this material is a repeat of what was said in plenary, but not all.

Outline of the Proposed Solution

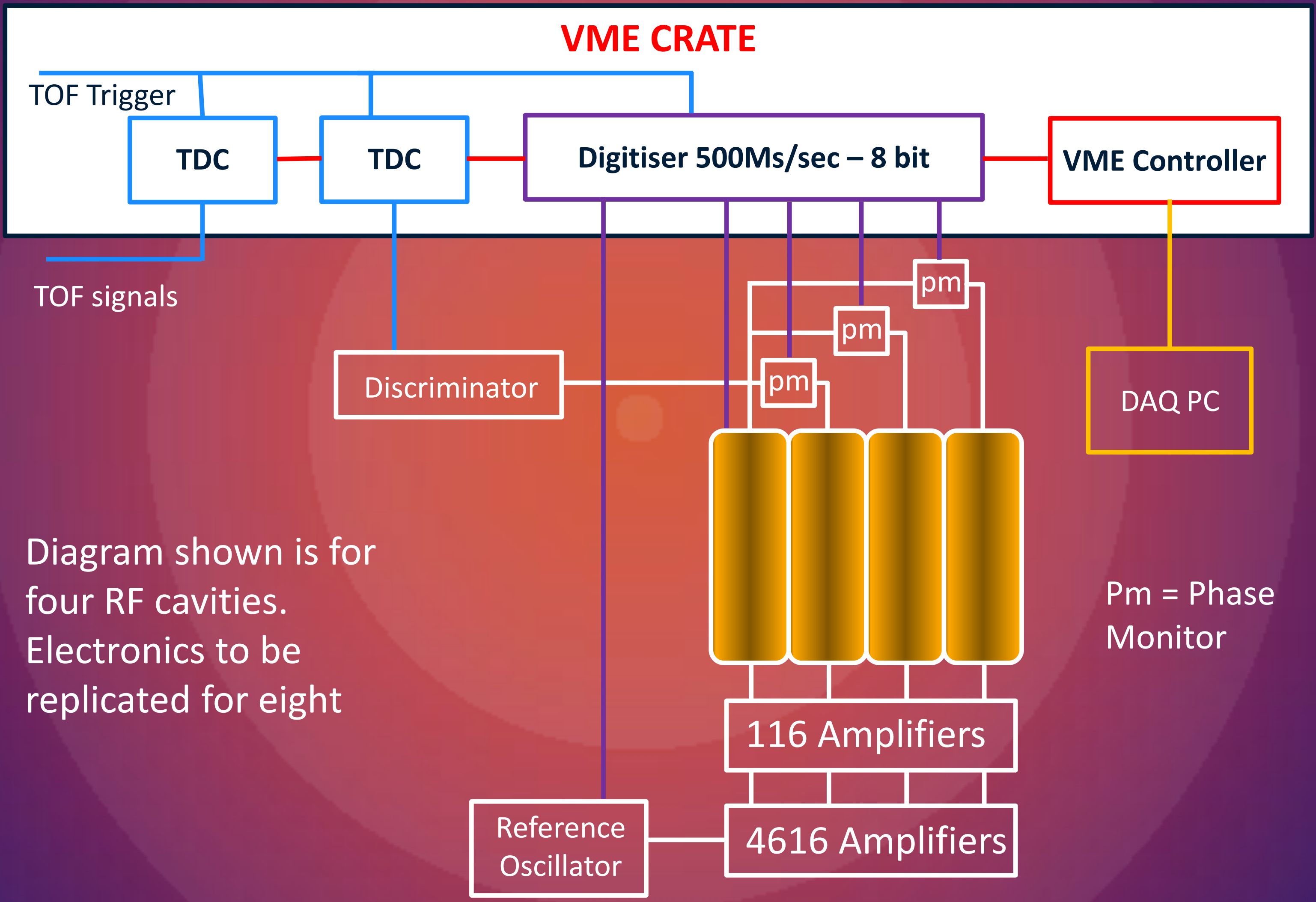


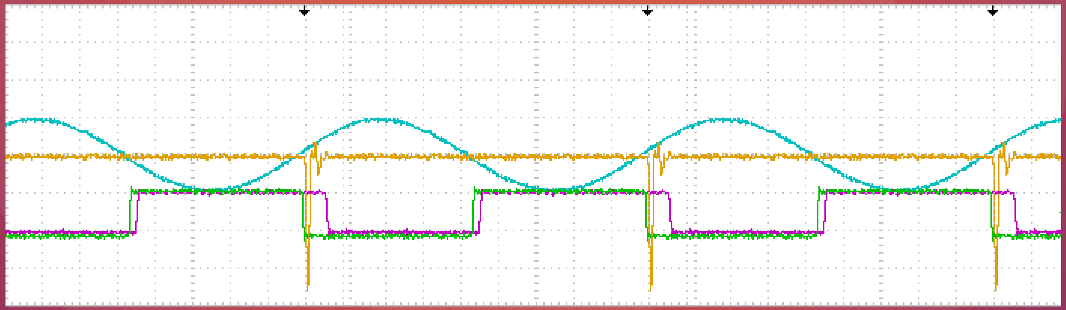
Diagram shown is for four RF cavities. Electronics to be replicated for eight

Pm = Phase Monitor

Discriminator - Function

A fast discriminator (level/zero crossing/fraction) will provide a series of timing pulses that would provide a mechanism to lock a given phase value of the RF to the TOF triggers.

By logging these triggers in a TDC synchronised to the TOF TDCs we should be able to time correlate the phase of the RF to events registered by the TOF TDCs. With this information it should be possible to reconstruct what the phase of the RF was when the muon traversed a cavity.

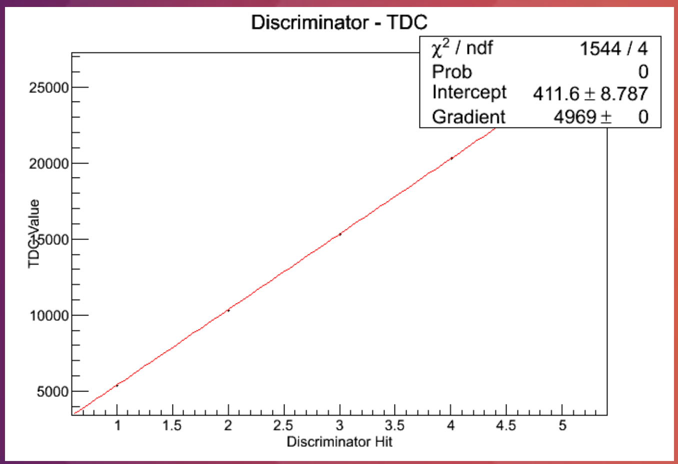


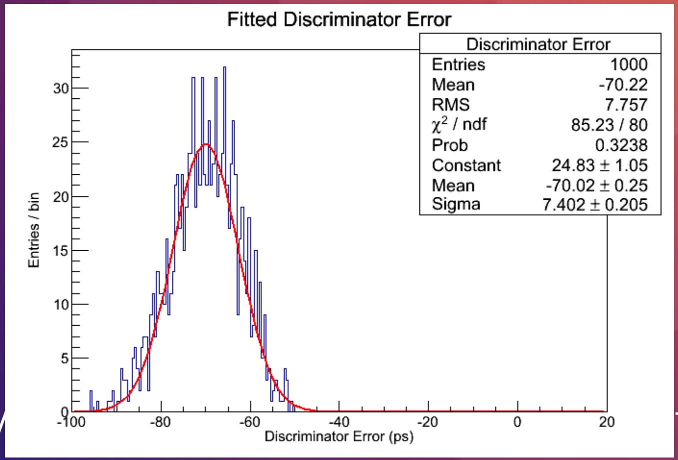
Note: This is a composite Image of LF Sine Wave (Few MHZ) with a discriminator to demonstrate the principle of generating regular timing pulses from the RF.

Discriminator Simulation

At the workshop I'd commented that I'd done some work simulating the discriminator and in principle I had good agreement between the discriminator triggers and the zero-crossing.

Exception was for a systematic that I hadn't understood when putting significant noise on the RF signal. Now I probably overestimated the noise but I still wanted to understand this.





Plotting Discriminator hit number vs TDC bin.

Note: no jitter on discriminator
no jitter on TDC
0.05% 1 sigma noise on signal

Gradient = RF time period
– Assumed known for fit

Intercept = phase shift – plotted against known phase shift in second plot

There is a systematic error, a time walk, that is dependent upon the level of applied noise to the RF signal.

Discriminator Simulation

The systematic turns out to be an error due to a slightly increased probability of the discriminator firing early when there is noise on a rising signal. I won't go through the maths here but I did an semi-analytical calculation for different levels of noise and compared with the simulation:

Noise 1σ	Observed Walk (ps) Simulation	Calculated Walk (ps)	Fraction
0	0	0	-
0.01	-8.3	-8.5	0.98
0.02	-21.5	-22	0.98
0.03	-37	-37	1.00
0.04	-53	-52	1.02
0.05	-70.02	-69	1.01

I should point out that I only get good agreement when the time-steps in both the simulation and calculation are small and similar, but with an understanding of the mechanism this isn't surprising.

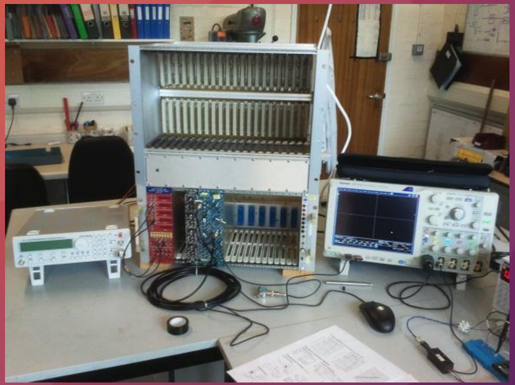
I'm not sure how much use, or how relevant this is, or will be, but it's interesting that a source of noise on the signal can produce a time-walk like this.

Now that I understand this, I would like to do some more simulations with discriminator jitter and TDC jitter.

Assembling a Test-Bench

We've spent a significant amount of time and effort putting together a test bench at Sheffield. We're getting there…

- 1 GHz Scope. ✓
- Sign Gen - Borrowed one but has had to be returned. ✗
- 500Ms/sec digitiser VME module - On loan from EMR. ✓
- 25ps TDC VME - On loan from TOF. ✓
- VME Crate – Borrowed one from RAL but it is damaged – We need another. ✗
- VME Link. ✓
- PC. ✓
- Discriminator - 100MHz CF/ZC/level but will probably require a new one >200MHz. ✓
- Software – To Discuss with Yordan. ✓



MICE

Cable Delay Measurements

The University Of Sheffield.

Using the histogram function on the scope to measure the mean difference in delay between two cables. (~75,000 samples on 10x oversample). Swap Channels and repeat. Statistical error at this number of samples should be insignificant.

Assuming a fixed systematic for each channel input on the scope…

$(d_1 + s_1) – (d_2 + s_2) = A$

$(d_2 + s_1) – (d_1 + s_2) = B$

$d_1 – d_2 = del(d) = (A-B)/2$

Swap sections of cable over and repeat.

I Seemed to be getting down to about ~10ps difference using this technique.

Plans

Once we have a full test bench it will be easier to plan a full schedule of the work.
At the moment I'm spending some time with the new scope familiarising myself with it and seeing how accurately I can measure cable delays/phase differences.

In the immediate future I can see the following to be useful:

1) Bench testing the phase monitors (evaluation boards from Hittite on loan from DL)

2) Bench testing the discriminator and evaluating the requirement for a faster one!

3) Setting up the software to talk over the VME and establish communication with the TDC and digitisers.

4) Feeding back what we find into the simulation to try and get a better model.

However all of this does require a complete Bench Test Setup which remains my priority. Hopefully we will be in a better position to report a more detailed plan by the next CM.

Conclusion

We have established a method of tackling the RF timing problem for MICE and have a clear way forward – good agreement amongst experts on the method at the RF workshop. – Timing very tight though...

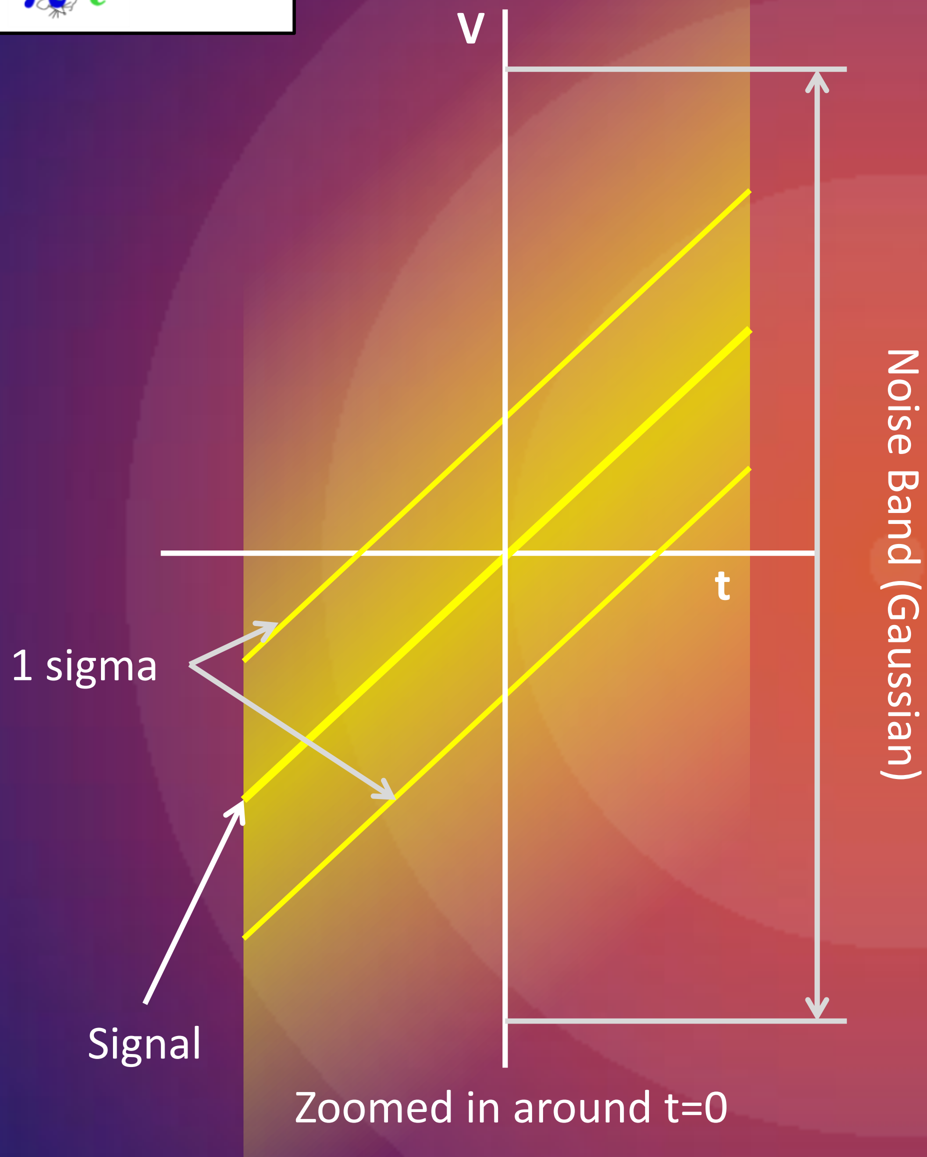
We have some simple simulation models that have pointed us in the direction as to what specification of hardware we need.

We are in the process of setting up a test-bench at Sheffield to make some measurements on the proposed hardware to see what performance we can actually achieve. Obtaining a fully functioning test bench is our current priority.

Although we have a good outline of what we want to achieve the 'Devil will be in the detail'. The construction of the test bench and some initial testing will drive the subsequent detailed plan for the RF timing. We hope to be much closer to this by the next CM.

EXTRAS

Additional Slide 1

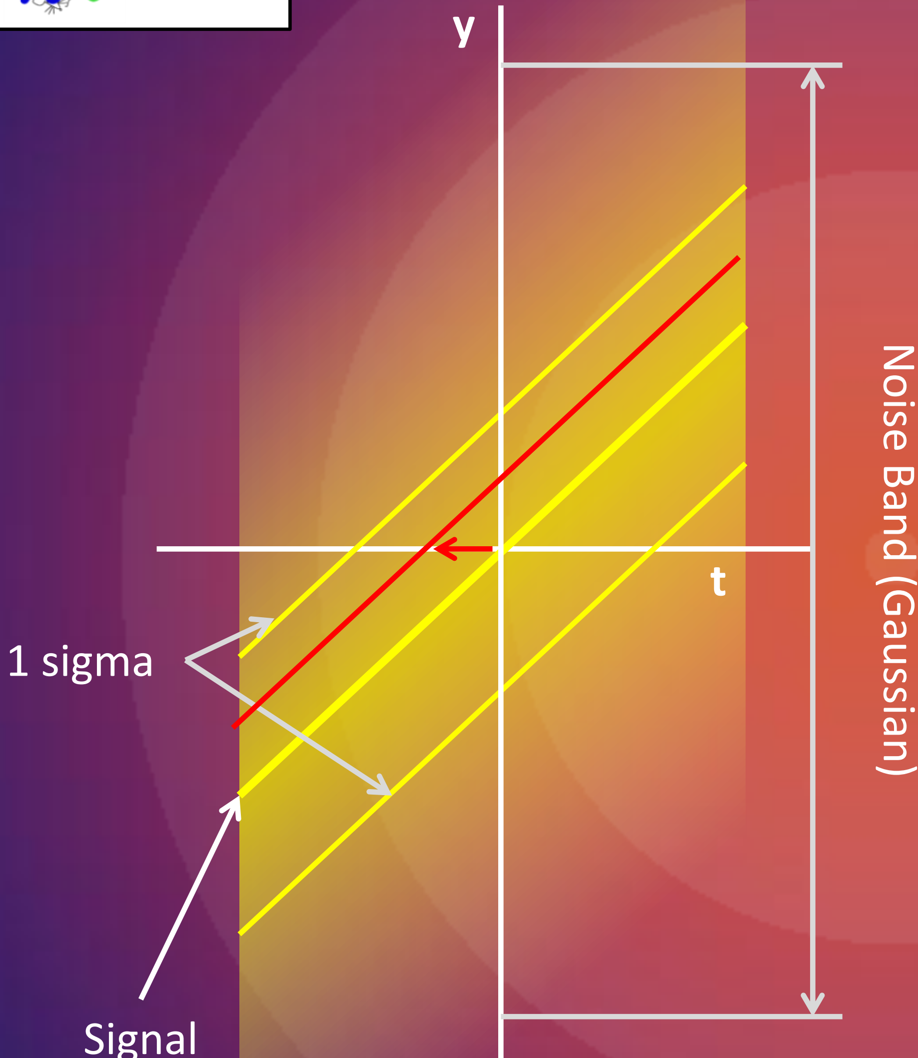


Assume zero crossing threshold (i.e. y axis)

Signal = A sin (ωt)
Gradient = Aω cos (ωt)
@ t= 0 Gradient = Aω

σ = kA (k = independent Constant)

Additional Slide 2



Zoomed in around t=0

Assume zero crossing threshold (i.e. y axis)

Signal = A sin (ωt)
Gradient = Aω cos (ωt)
@ t= 0 Gradient = Aω

σ = kA (k = independent Constant)

Assume that red line is effective signal location and at t=0 this intercepts at $h_0 = j\sigma = \mu$

This crosses a threshold at a time $-t_0$
Where $\tan \theta = j\sigma/t_0 = A\omega$

$\Rightarrow$ $t_0 = j\sigma/ A\omega = \mu/A\omega$

Additional Slide 3

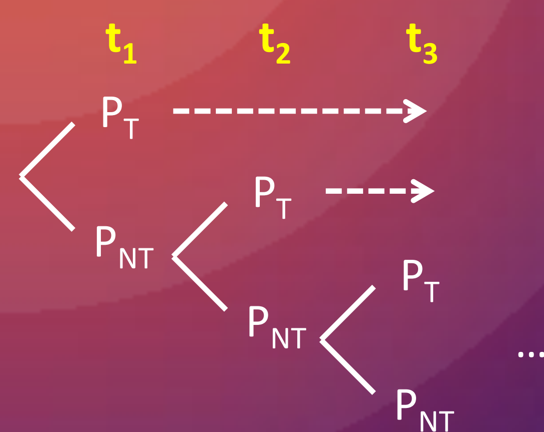
The Gaussian lies across the y axis and at t=0

$$F\{y(t=0)\} = \frac{1}{\sigma\sqrt{2\pi}} \exp -\frac{y^2}{2\sigma^2}$$

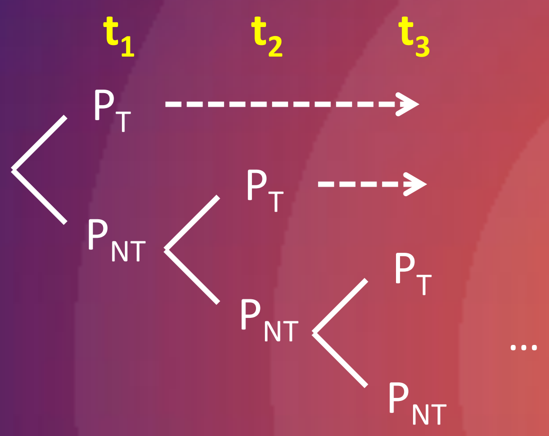
This represents a normalised Gaussian!

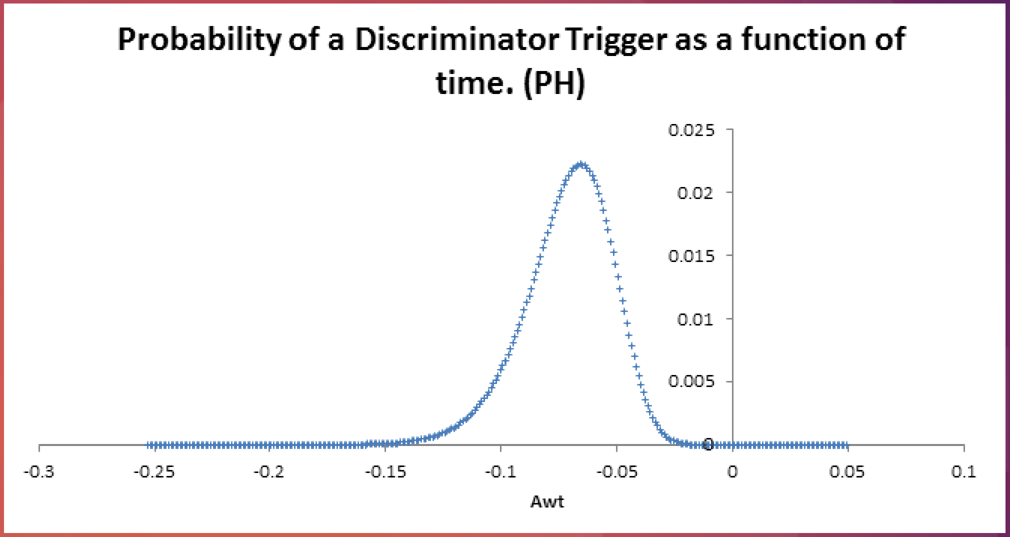
Instead of moving the Gaussian in y as a function of t just assume that the trigger level is scanning through the Gaussian at a rate of Awt. Therefore the probability of a trigger at time t is the integral of dP(t) from –inf to t, presuming there was no previous trigger where:

$$dP(t) = \frac{1}{\sigma\sqrt{2\pi}} \exp -\frac{(A\omega t)^2}{2\sigma^2} dt$$



Additional Slide 4





Find the mean through numerical means and this gives the time that a trigger is most likely.

This indicates that adding noise will on average give an early trigger, i.e. a time walk.

Good agreement with simulation provided that delta(t) is small. The accuracy of the algorithm seems dependent upon this.