Timing performance measurements of the INO-ICAL Resistive Plate Chamber (RPC) using Constant Fraction Discriminator (CFD)

Harsh shah

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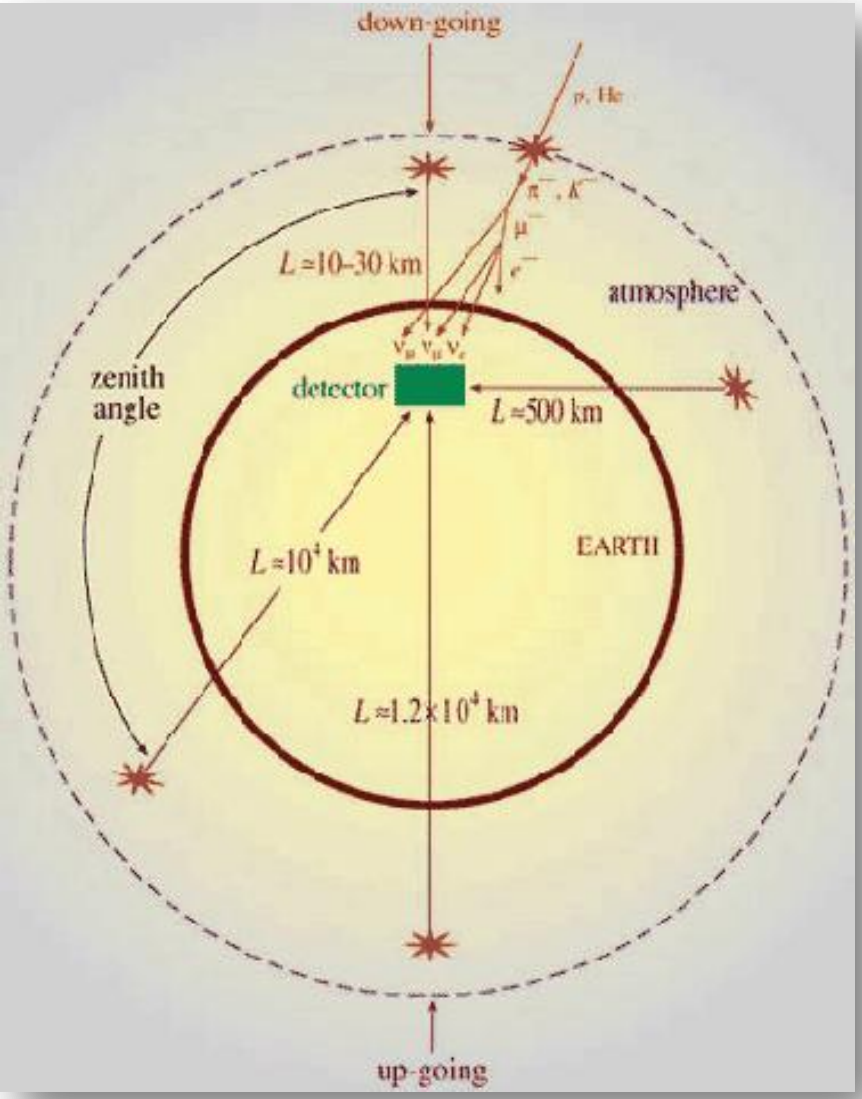
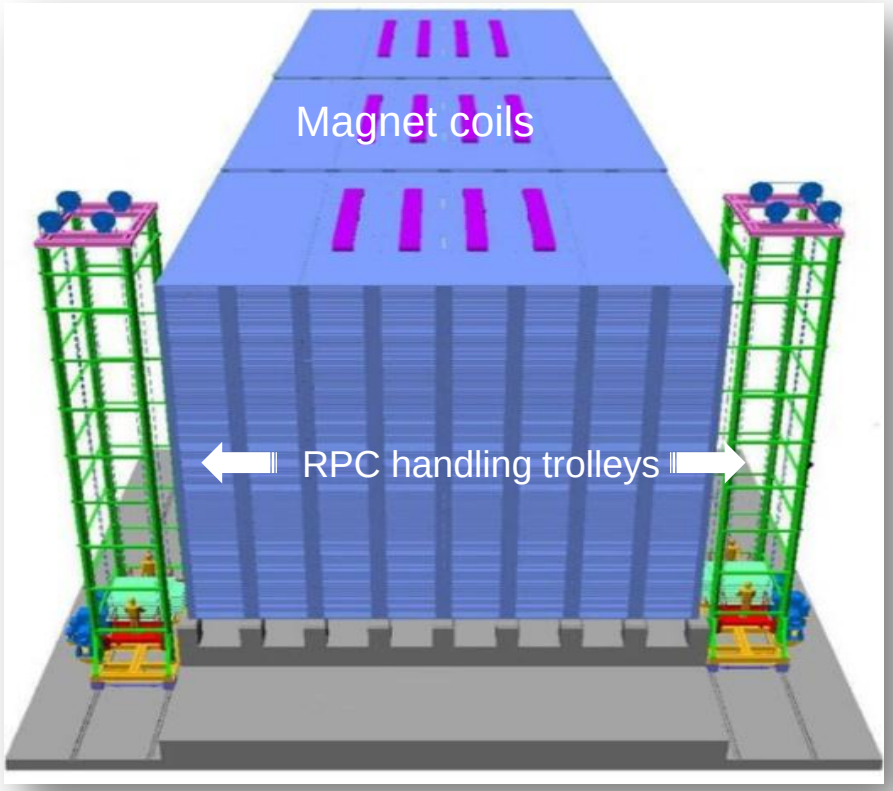
DHEP

Importance of time resolution for INO's ICAL detector



- The motive of ICAL detector is to solve some of the challenging problems related to atmospheric neutrinos.
- Neutrino oscillations are one among those problem.
- Directionality is a major criterion to solve such questions.
- Time resolution is a key point.



Errors in Timing measurement techniques

Walk

- It is concerned while measuring time at constant threshold.
- For two different signals with varying amplitude, time signal generates at different time.
- Requirement of specific amount of charge may also concern with time walk.

Jitter

- It is electronic effect.
- With modified instruments it can be reduced.
- No way to eliminate completely.

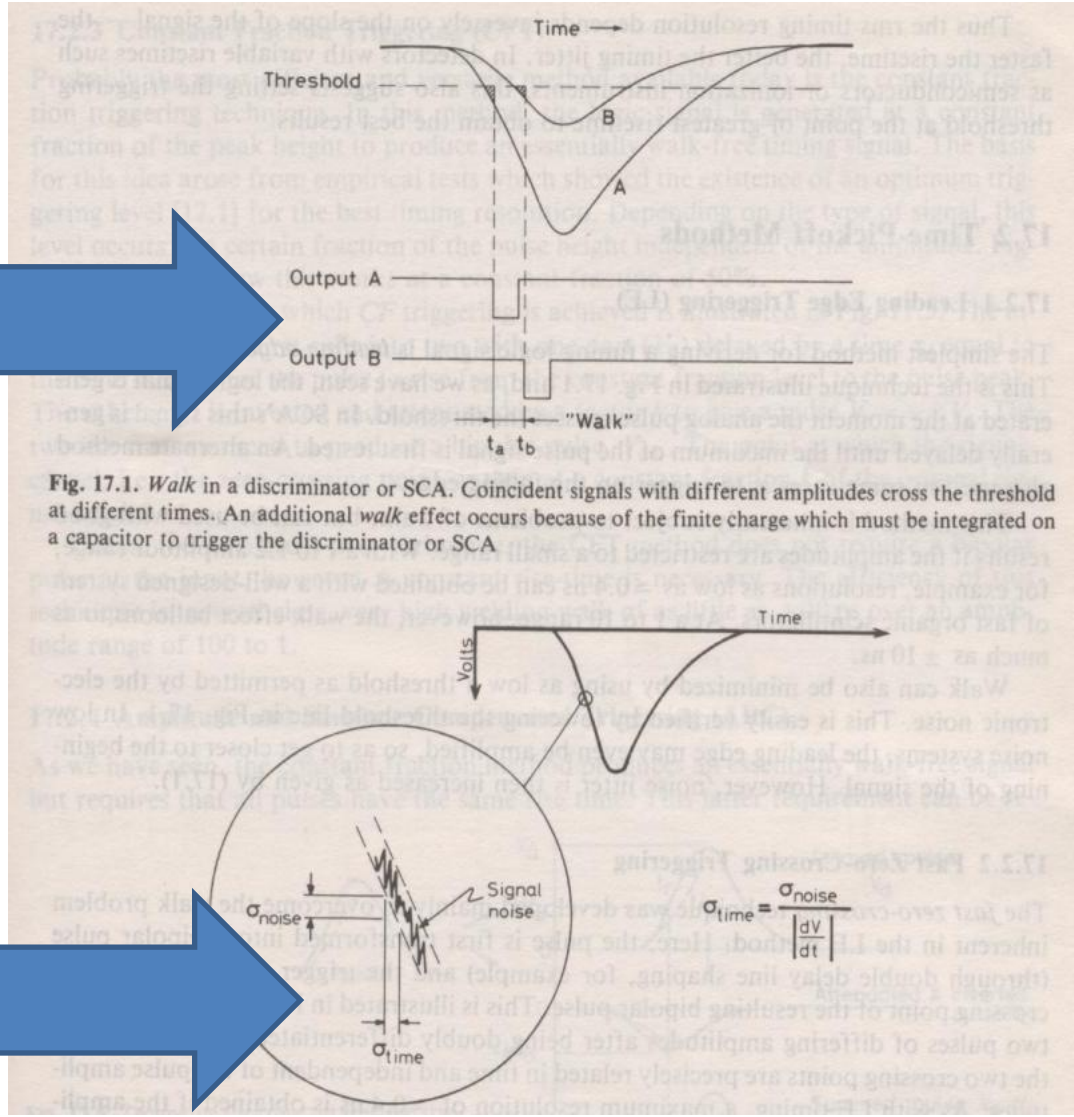


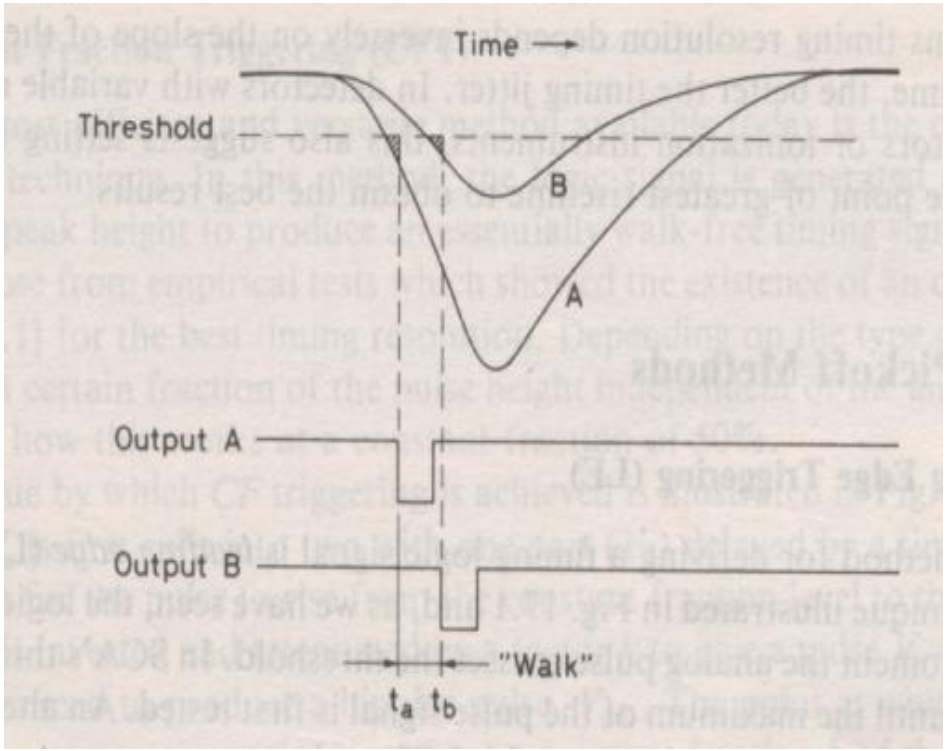
Fig. 17.1. *Walk* in a discriminator or SCA. Coincident signals with different amplitudes cross the threshold at different times. An additional *walk* effect occurs because of the finite charge which must be integrated on a capacitor to trigger the discriminator or SCA

-W. R. Leo, Techniques for nuclear and particle physics experiments

Techniques we used

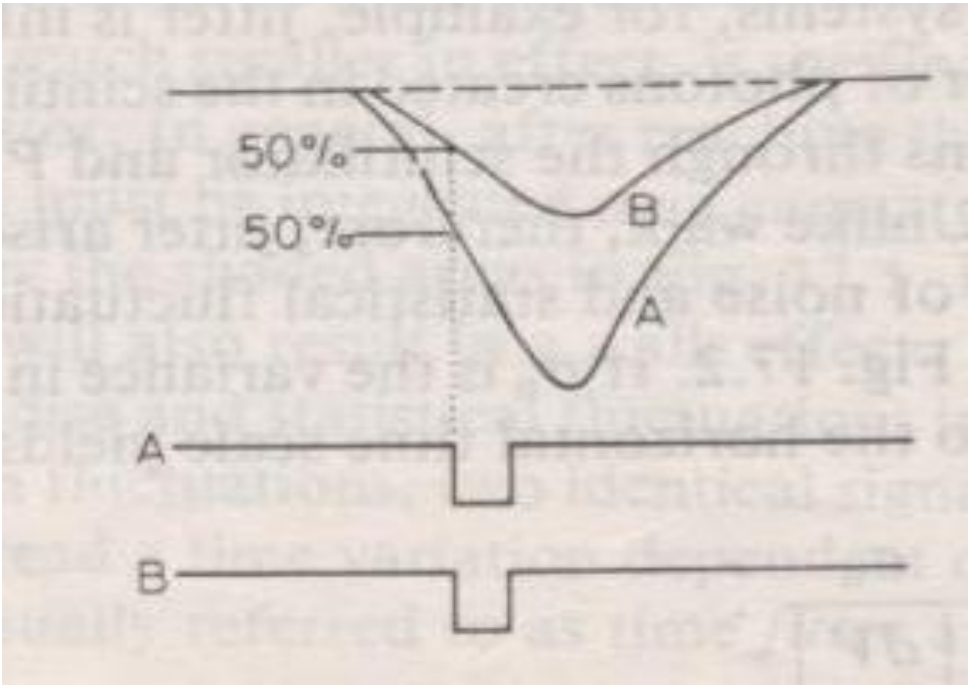
Leading edge triggering (LED)

- It is most widely used triggering method for time measurements in particle physics experiments.
- The signal is generated at a constant threshold.
- For small amplitudes this method can give good results.



Constant fraction discriminator (CFD)

- i/p pulse splits into two: (a) delayed signal, (b) attenuated and inverted signal.
- The delay is adjusted in such way that the peak of the attenuated signal matches with the constant fraction of the inverted signal.
- The signal is generated at the zero crossing of the sum.



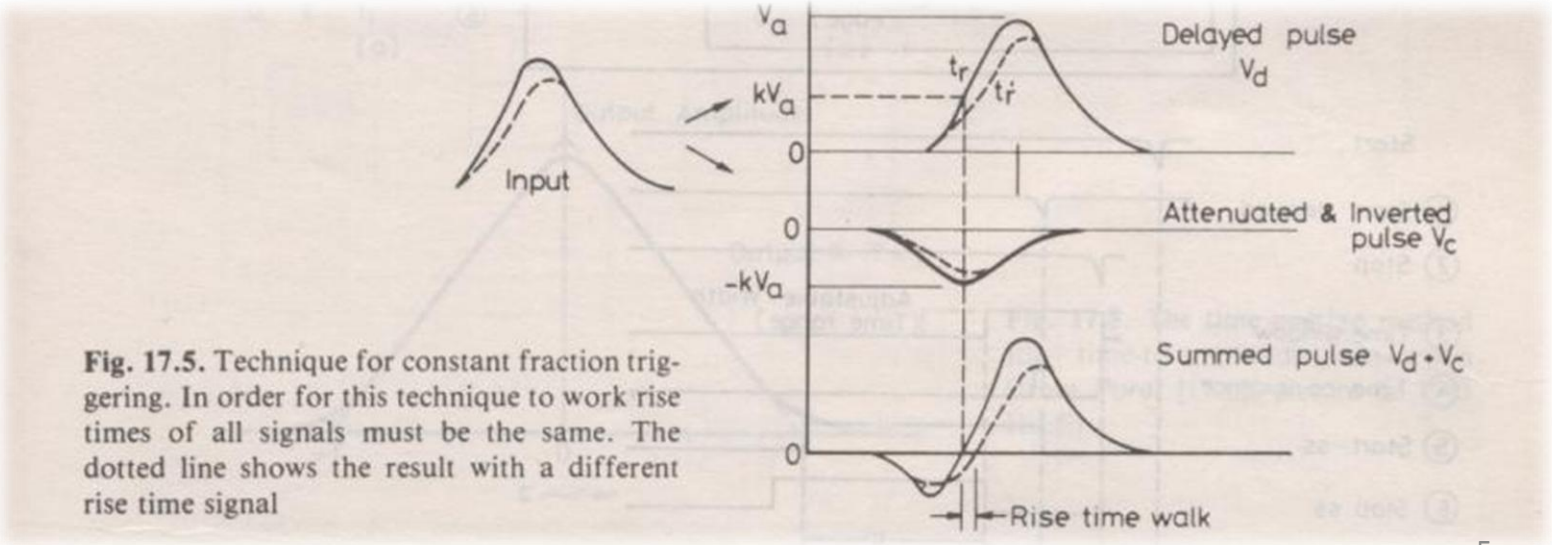
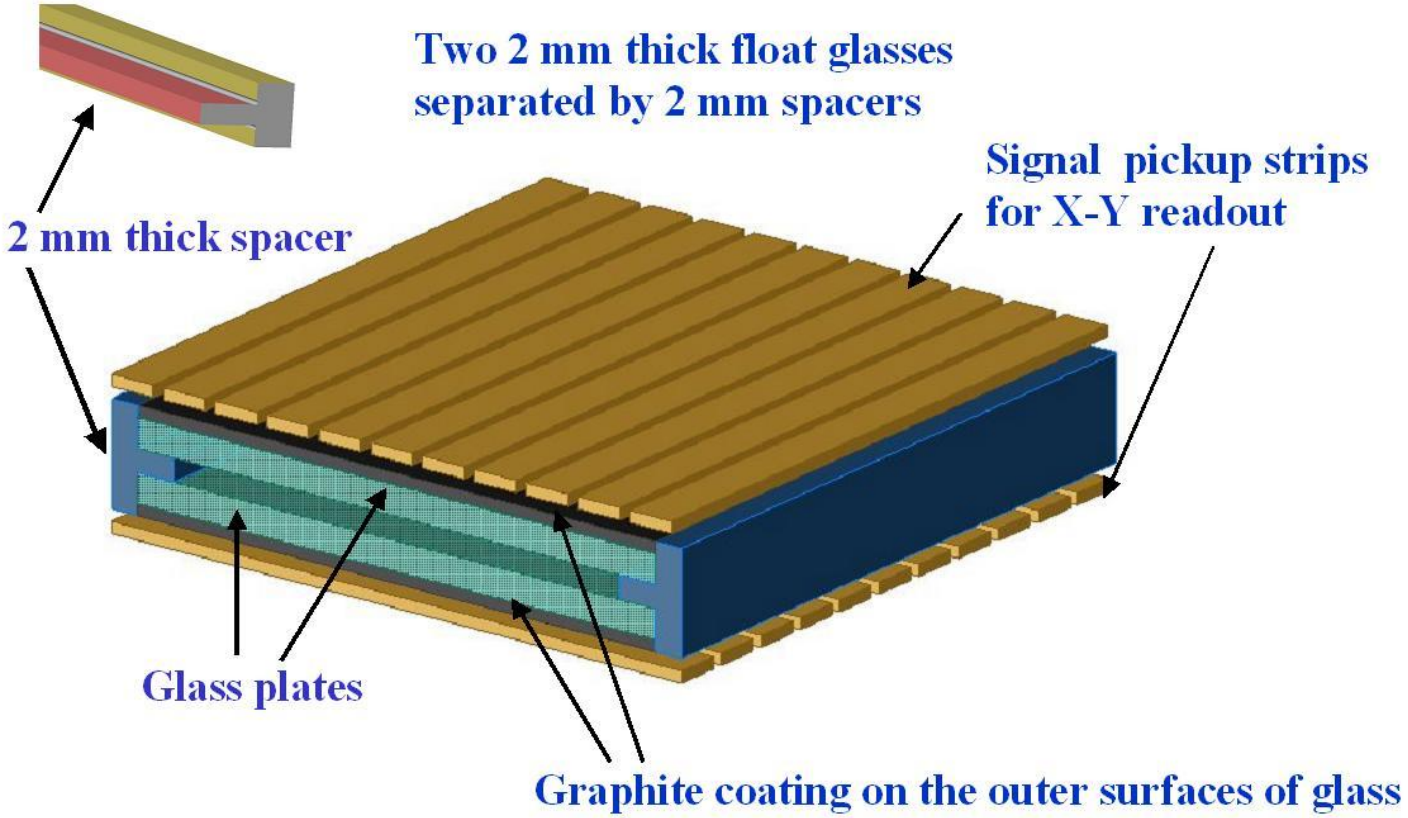
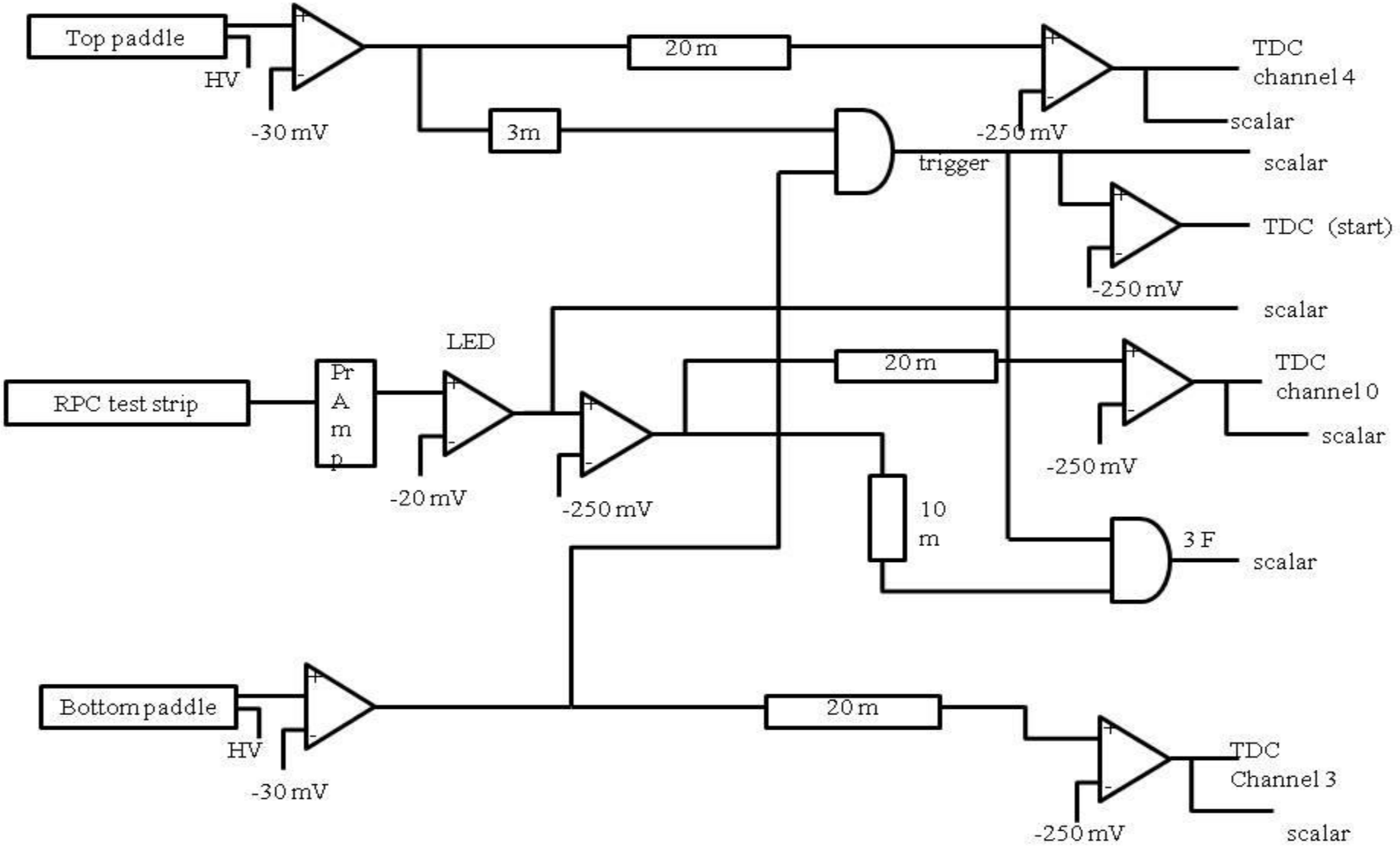


Fig. 17.5. Technique for constant fraction triggering. In order for this technique to work rise times of all signals must be the same. The dotted line shows the result with a different rise time signal

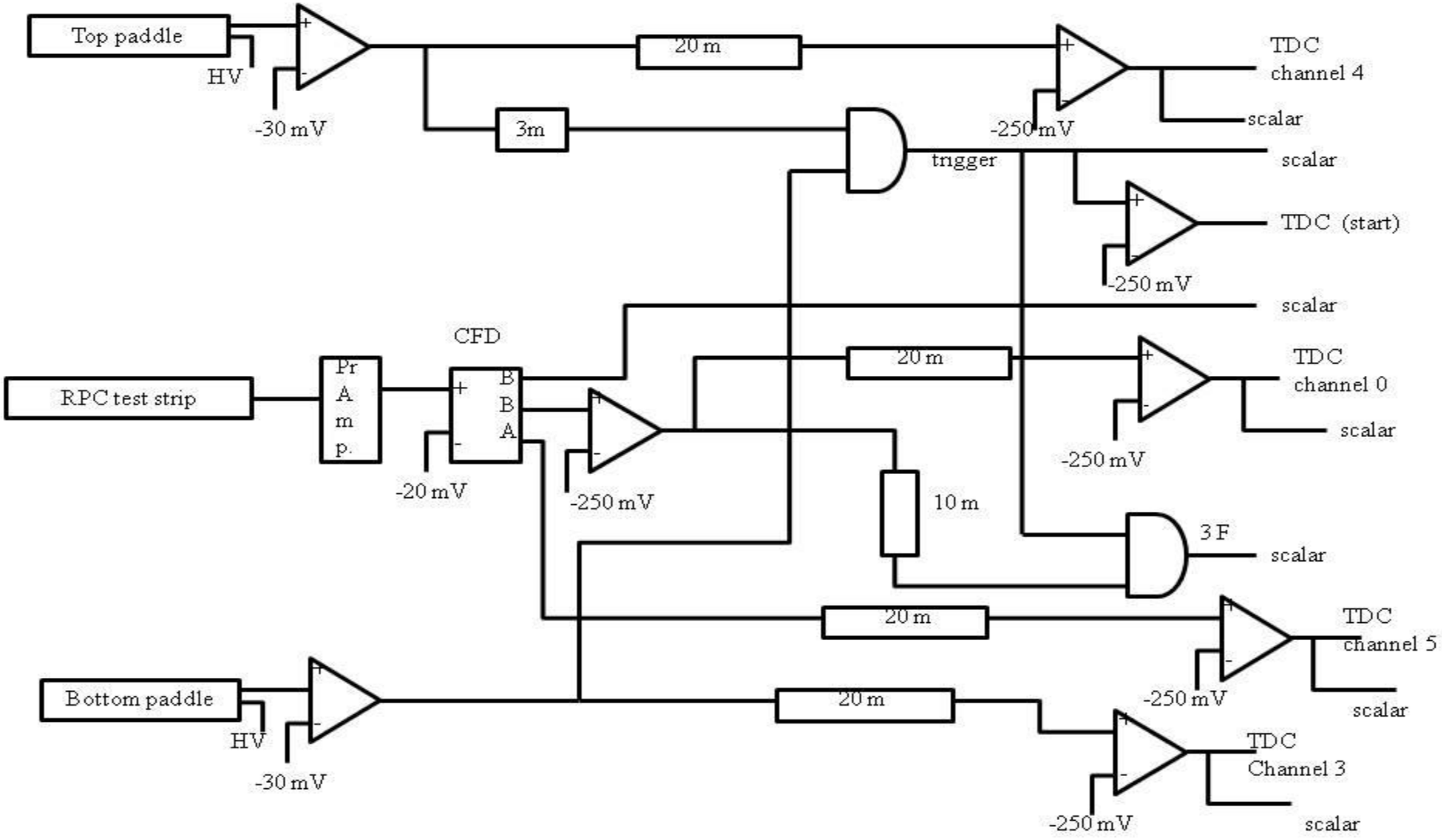
Resistive Plate Chambers (RPC)



LED


Top paddle
HV
-30 mV
20 m
3m
-250 mV
TDC
channel 4
scalar
trigger
scalar
TDC (start)
-250 mV
scalar
LED
RPC test strip
Pr
A
m
p
-20 mV
-250 mV
20 m
TDC
channel 0
scalar
-250 mV
10
m
3 F
scalar
Bottom paddle
HV
-30 mV
20 m
TDC
Channel 3
-250 mV
scalar

CFD


Top paddle
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TDC (start)
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scalar
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RPC test strip
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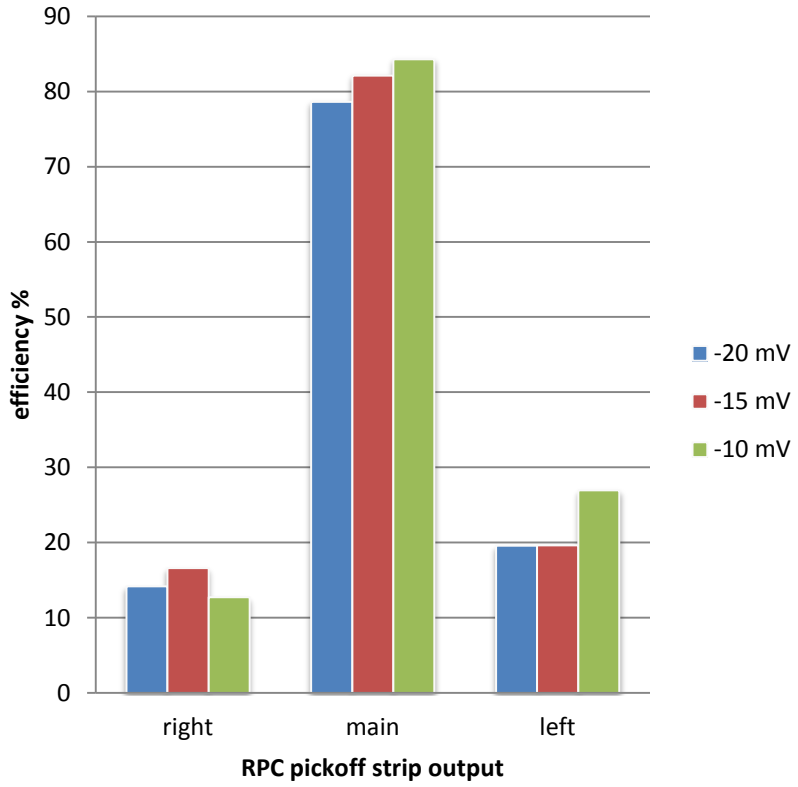
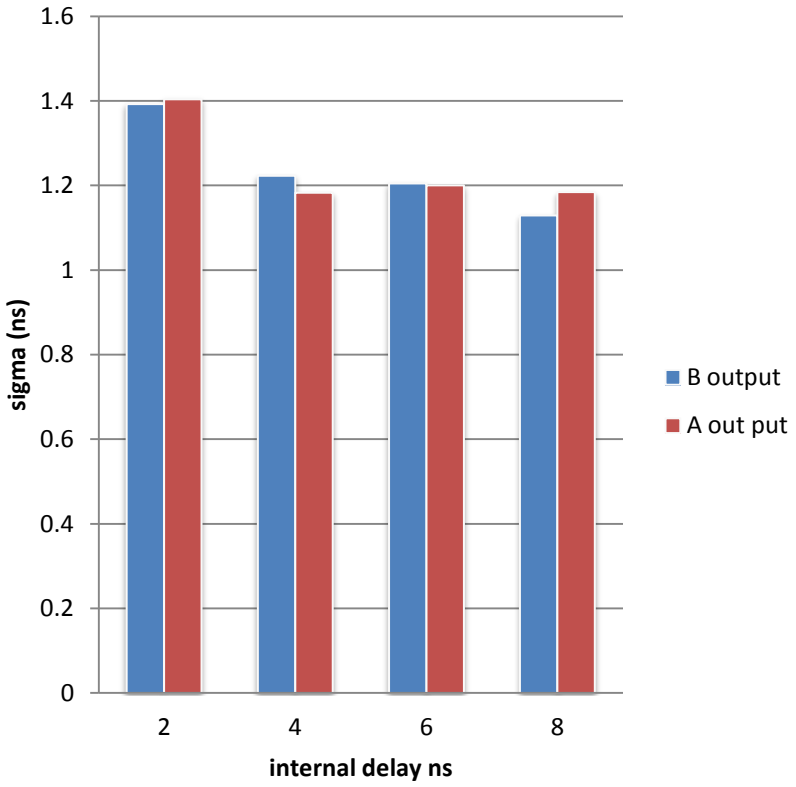
A
m
p.
B
B
A
-20 mV
-250 mV
20 m
TDC
channel 0
scalar
-250 mV
10 m
3 F
scalar
20 m
TDC
channel 5
-250 mV
scalar
Bottom paddle
HV
-30 mV
20 m
TDC
Channel 3
-250 mV
scalar

Tests with CFD

Efficiency with different threshold



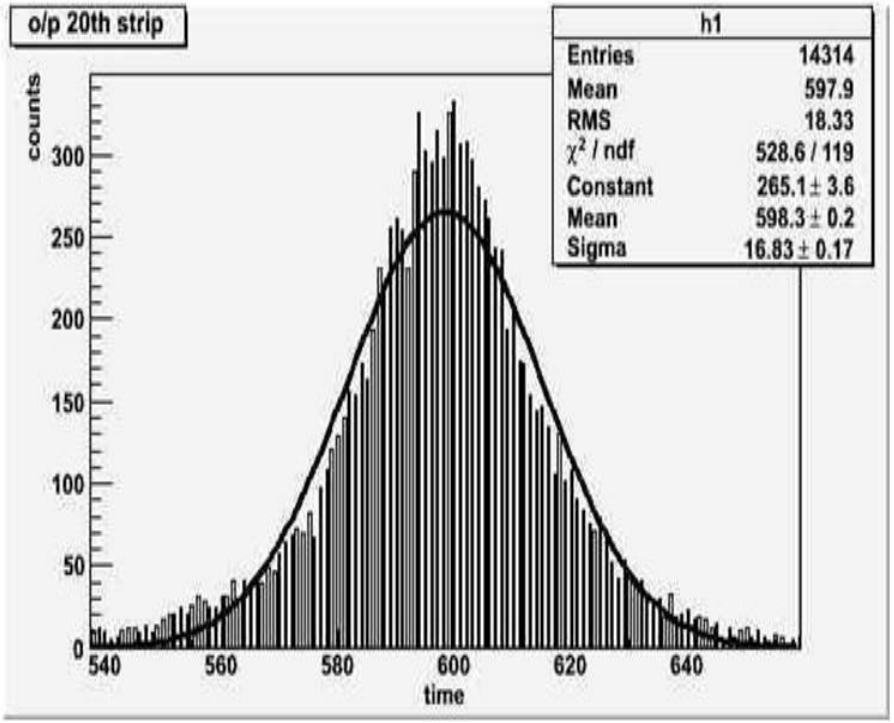
Time resolution(ns) with different internal delay



Time performance comparison

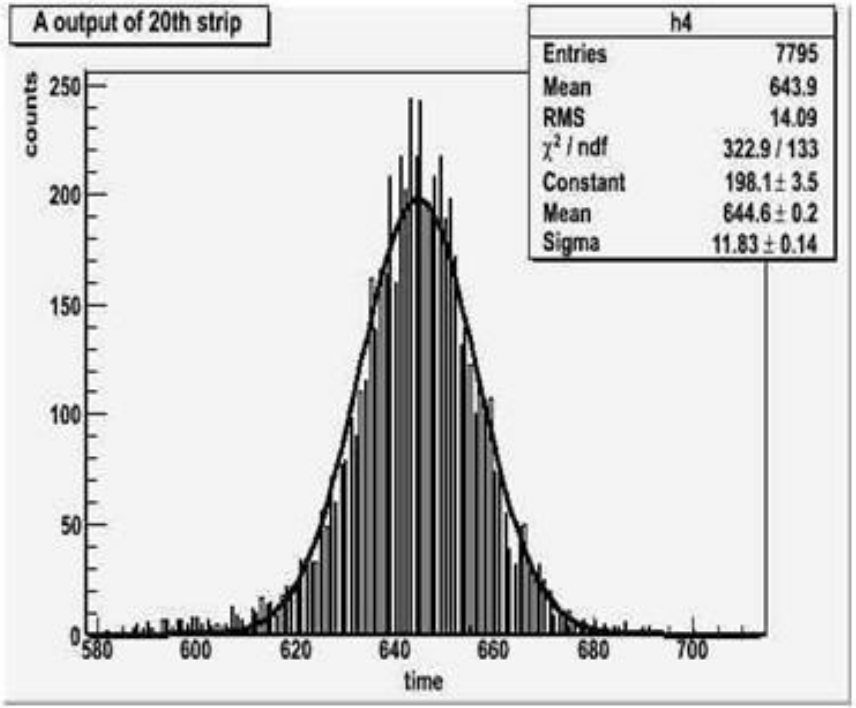
LED

- 20th strip



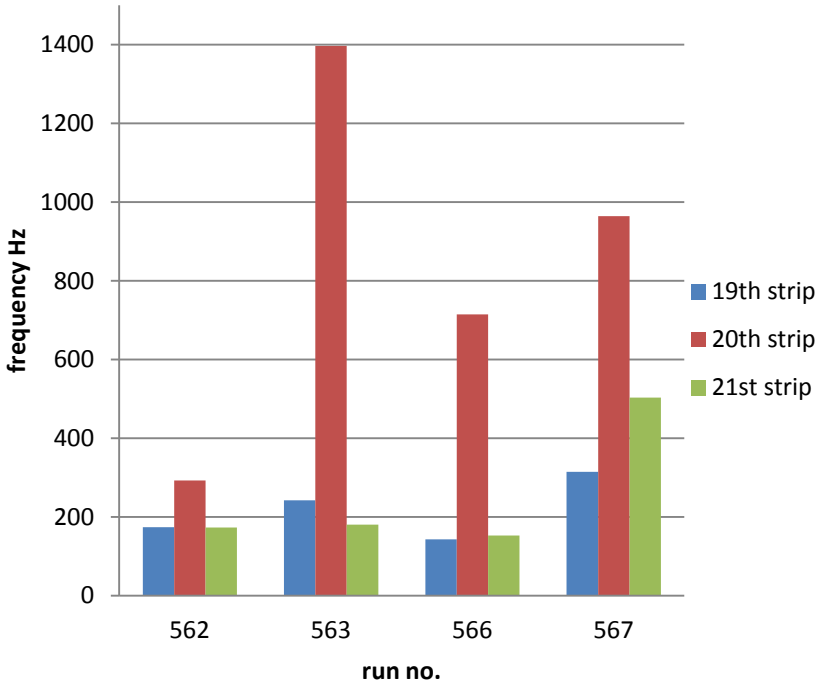
CFD

- 20th strip

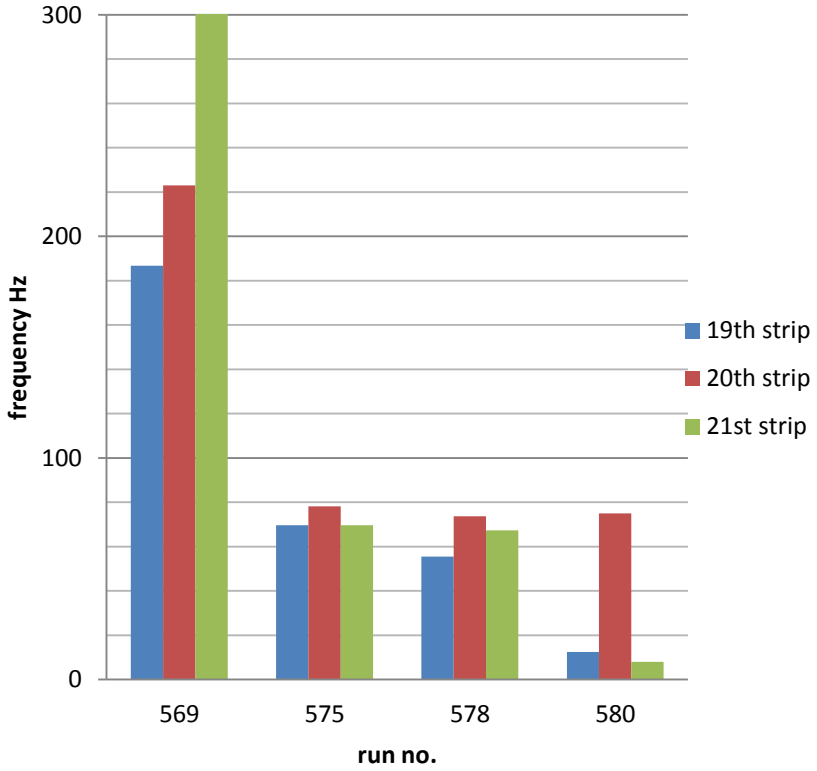


Noise rate

LED

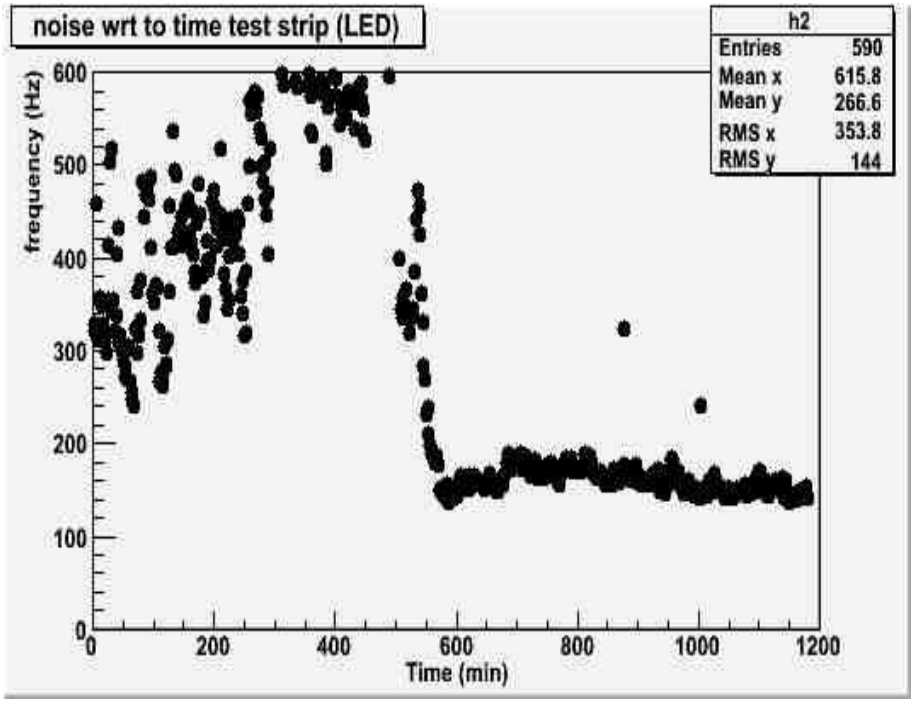


CFD

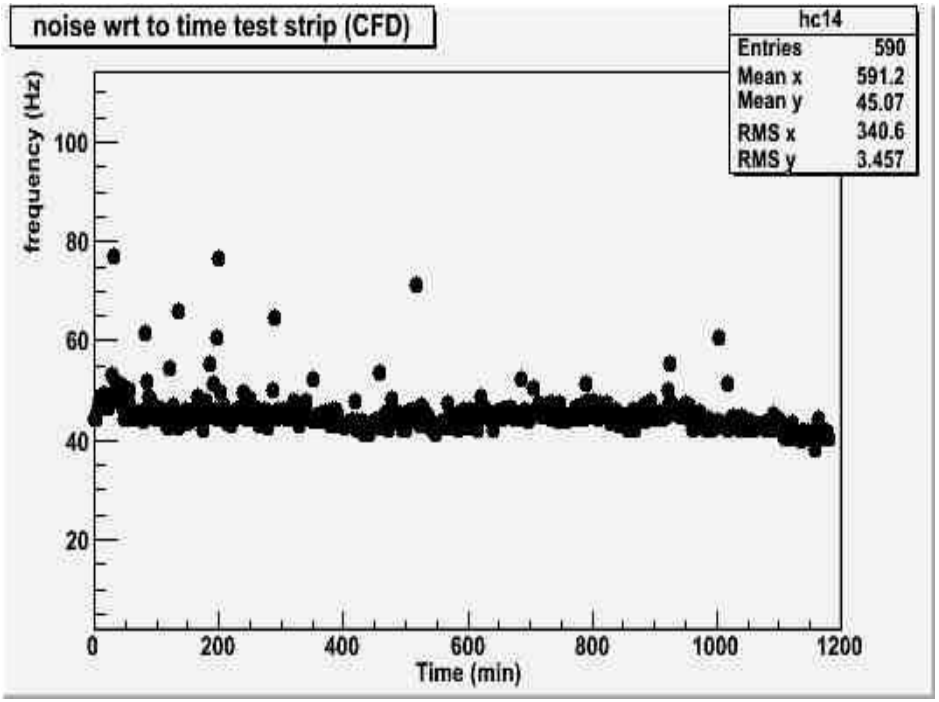


Noise rate variation with time

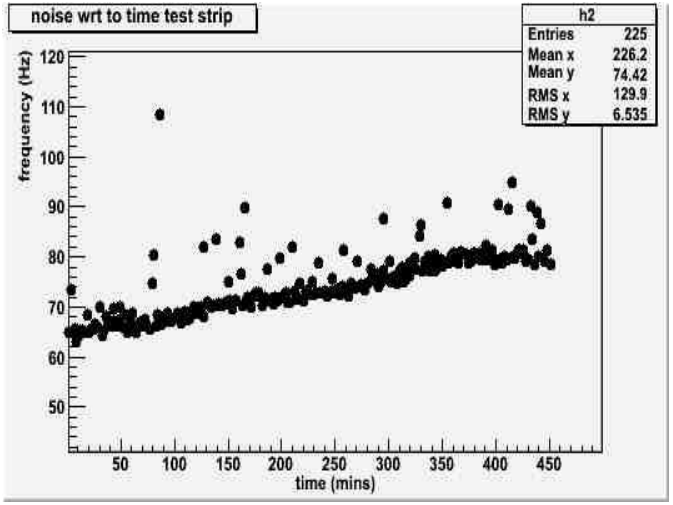
LED



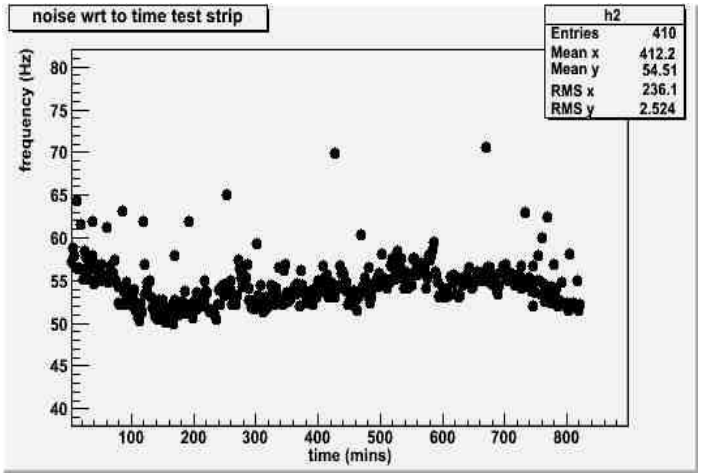
CFD



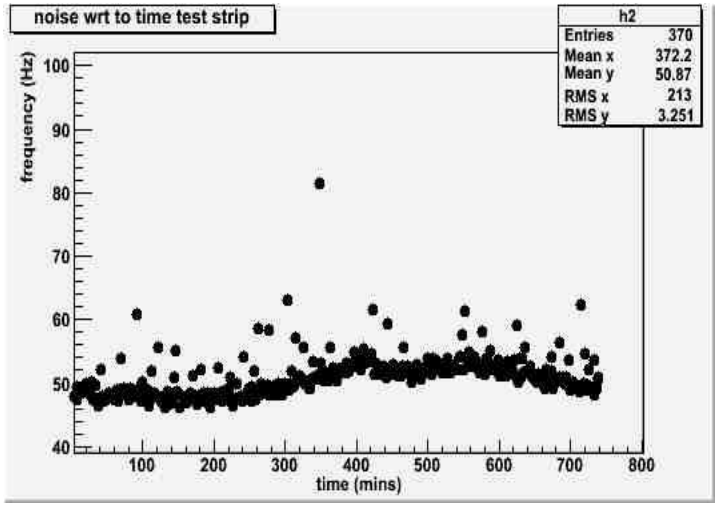
Noise rates as a function of threshold in CFD



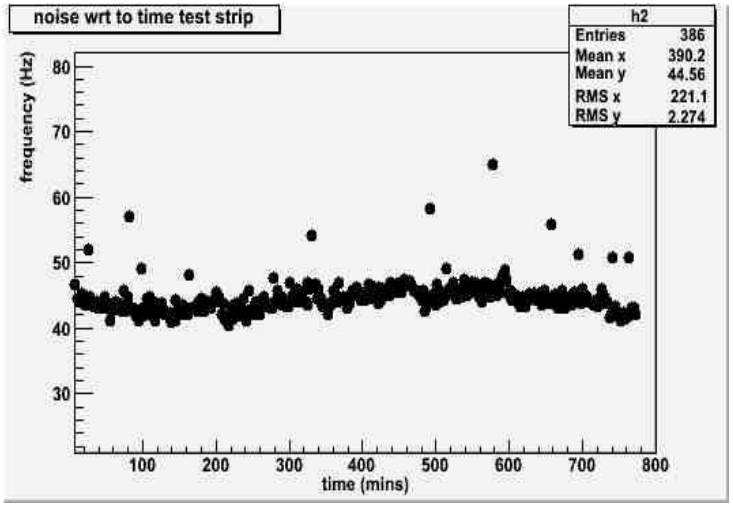
-10 mV threshold



-15 mV threshold



-20 mV threshold



-25 mV threshold

comparison

Type of triggering	σ (ns)		Efficiency of test strip (%)		Noise in test strip (Hz)	
	20^{th} strip	9^{th} strip	20^{th} strip	9^{th} strip	20^{th} strip	9^{th} strip
Leading edge	1.68	1.89	83.54	89.24	366.7±183.9	268.8±76.8
Constant fraction	1.18	1.57	79.49	82.93	78.0±7.2	52.8±3.7

conclusions

- There is significant improvement in time resolution by CFD
- The noise level remains almost stable even with the change in threshold in CFD
- Our signals are of varying amplitude and rise time. Hence LE is not a suitable option.
- A CF technique with optimized delay, fraction and threshold will be and ideal option.

Thank you !