# Time of Flight Determination with SamPic

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# Context of the study

In January 2015

- SamPic acquisition software works fine
- Analysis software developped by Matthias Saimpert & Nicola Minafra. Early stage of developpement.

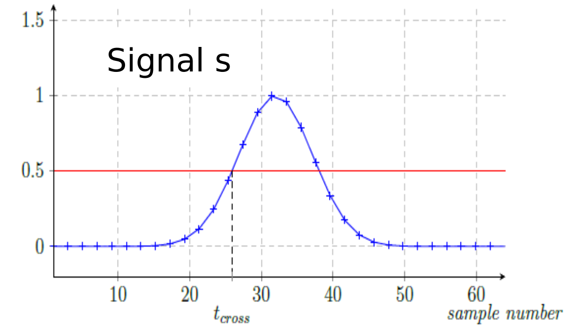
➢ Goal : Improve the Analysis Software, implement effective algorithm and test them with detectors

➢ Results : Added new features to the software. Tested new methods with SamPic and Silicon detectors

# The Algorithms for time determination

- Constant Fraction Discriminator

$$Time = s^{-1}(ratio * maximum)$$



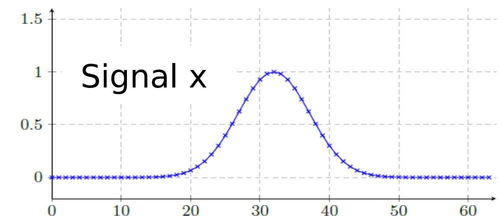

- Cross correlation

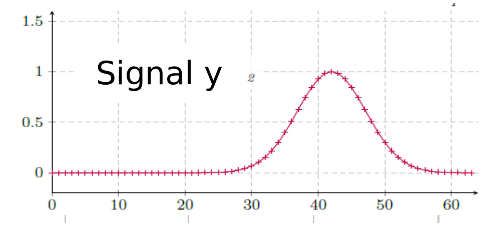
For two signals to compare x and y:

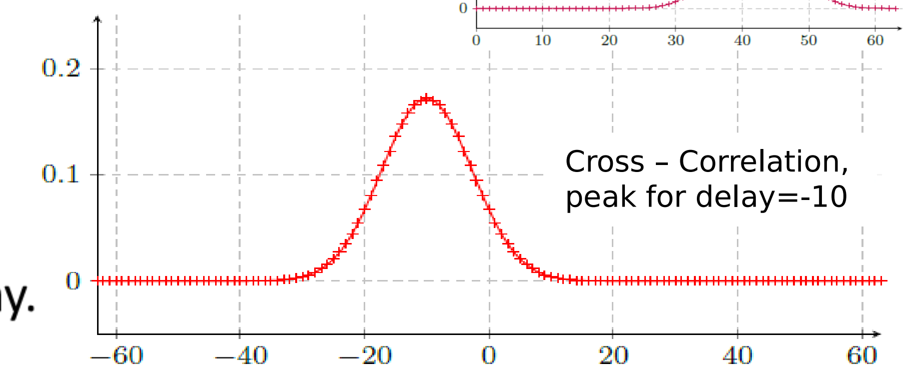
i. The normalized cross correlation calculates for d in [-64, 64]:

$$r = \frac{\sum_i [(x(i) - mx) * (y(i-d) - my)]}{\sqrt{\sum_i (x(i) - mx)^2} \sqrt{\sum_i (y(i-d) - my)^2}}$$

ii. The maximum of the correlation function is chosen as optimal delay.

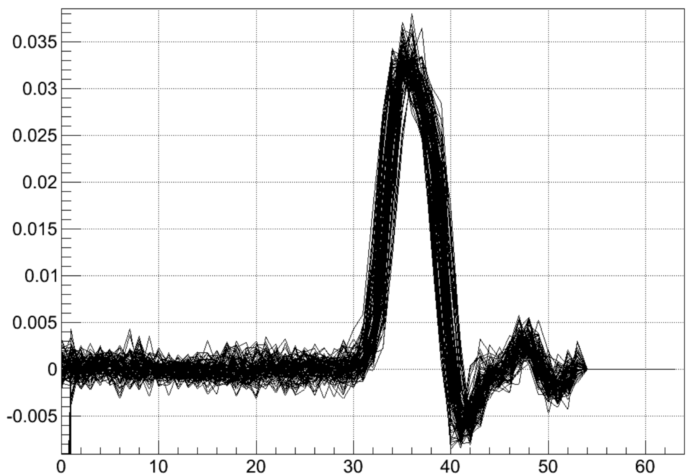


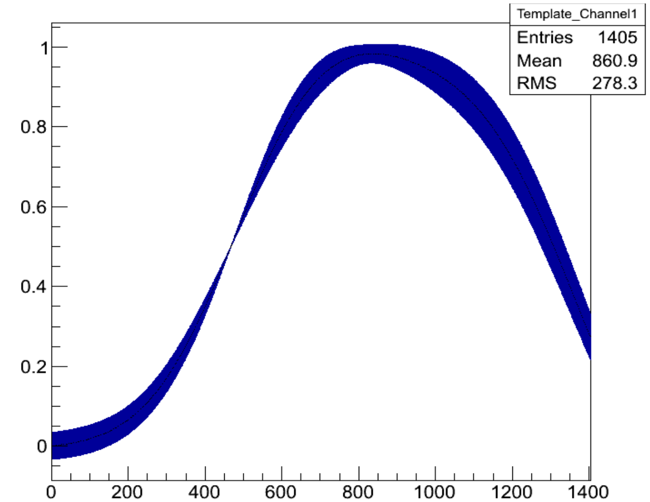

* Figures from H. Grabas 2013

# Templates: Reference patterns for cross correlation




Signals measured, 35mV - 0.8 ns risetime

**CFD** →



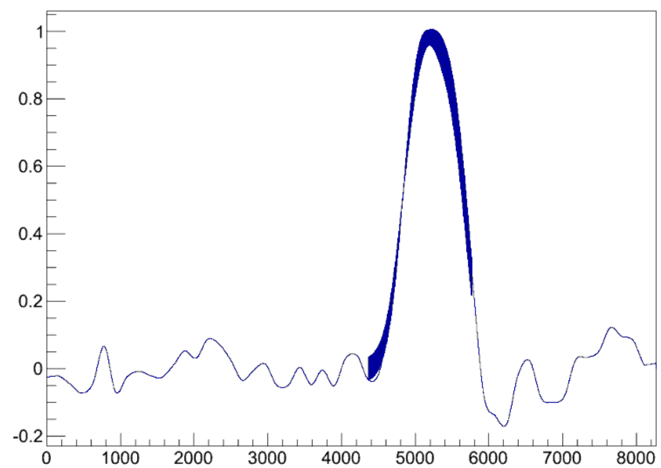

Template Channel 1

**Experimental Conditions:**

- LeCroy pulse generator
- 1 signal separated in two using a T

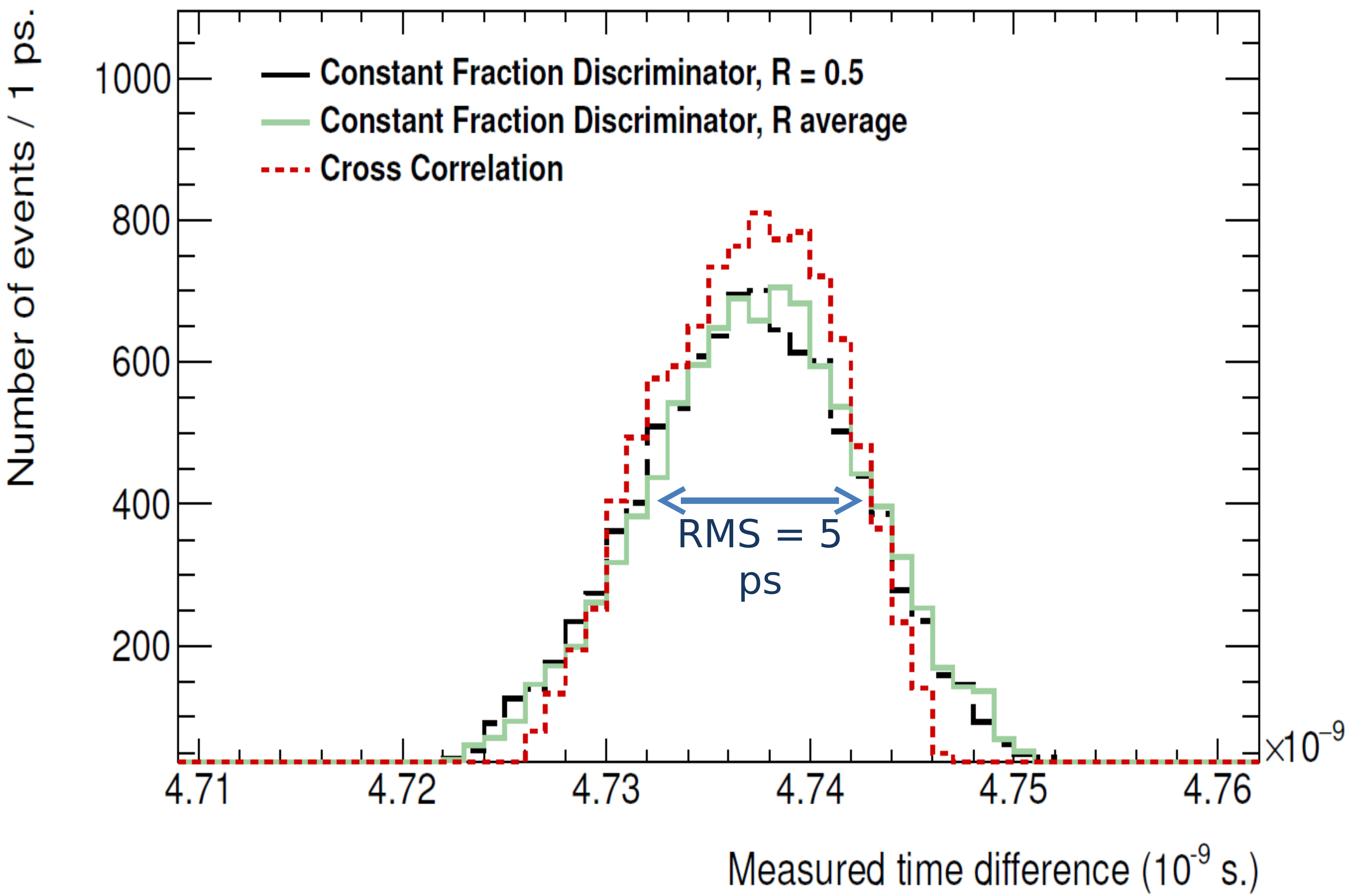
**Characteristics of the signals:**

- Very short rise time
- Great repodocibility of the signal.
- Sampling frequency was 6.4 GS/s




Synchronization between template and signal

# First results with the electronically generated signals



# First results with the electronically generated signals

**Performance tests with different amplitudes:**

-- The pulse generator was used to vary the amplitude of the pulses.

- Cross correlation improves performance in particular in situation of low “signal-to-noise”

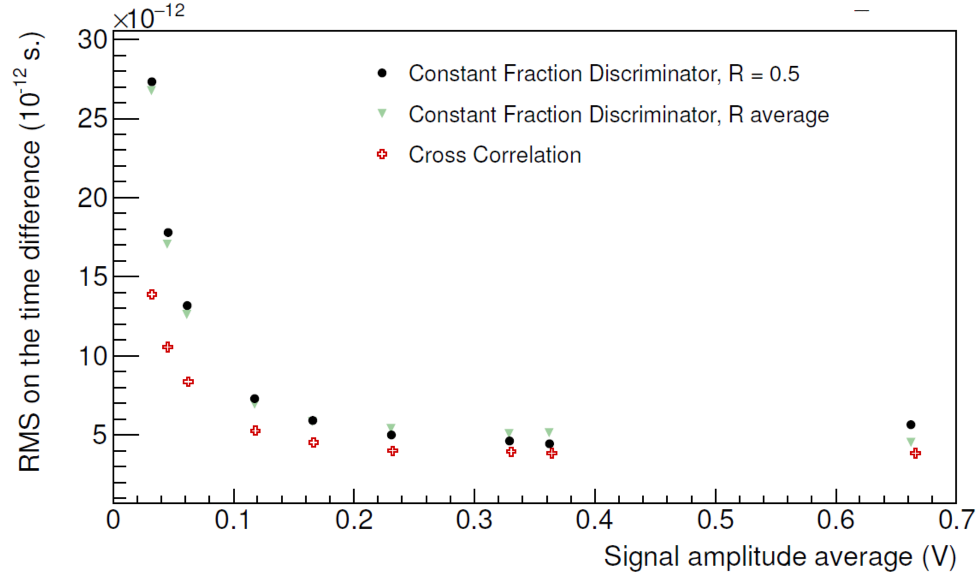
**Performance tests with different delays:**

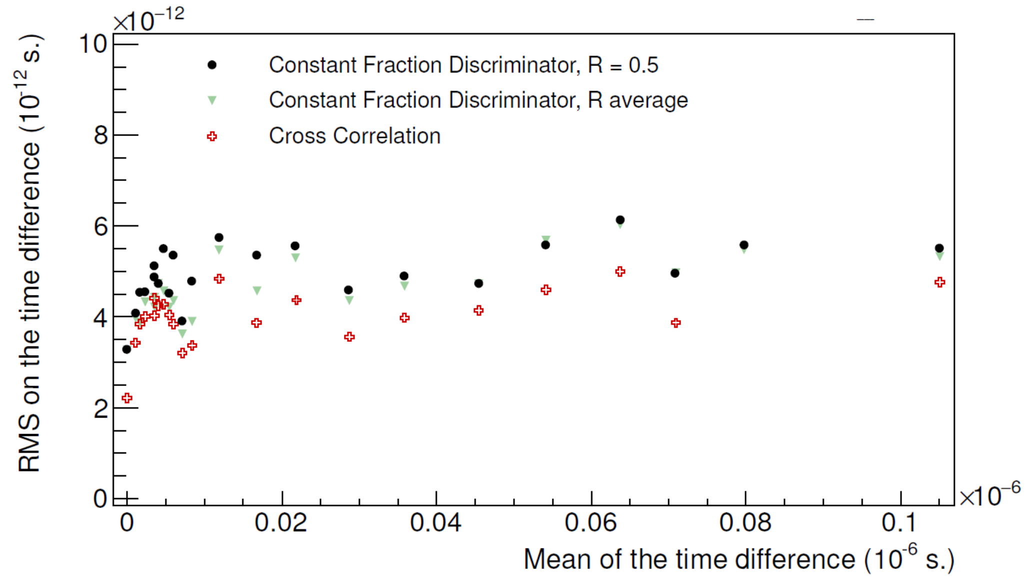
-- The length of the cable was used to vary the delay between both pulses.

- Signal distortion and attenuation for high delay (due to cable length and skin effect).

**50 % attenuation at 100 ns delay**

- The performances are not sensitive to the delay



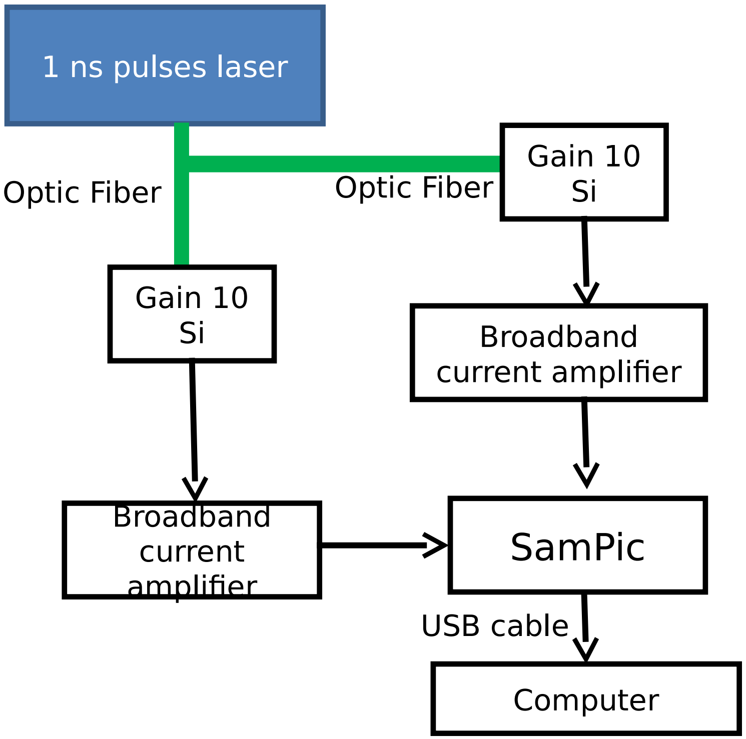



# Results with Laser – Broadband Amplifier – Gain 10 Si

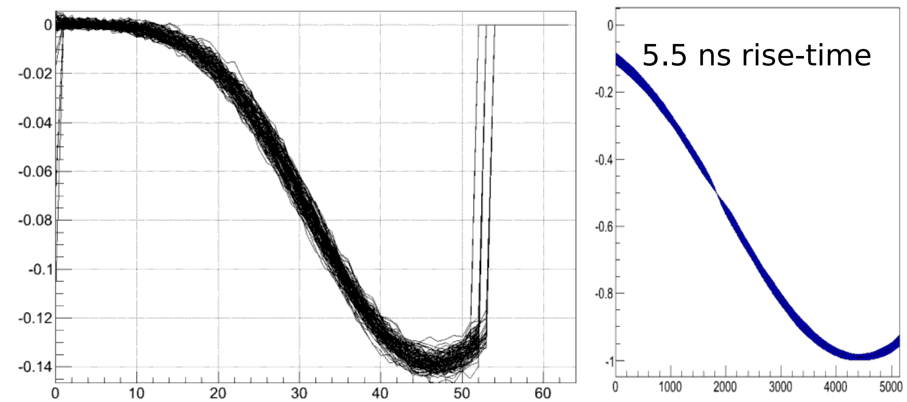
Performance tests with different amplitudes:

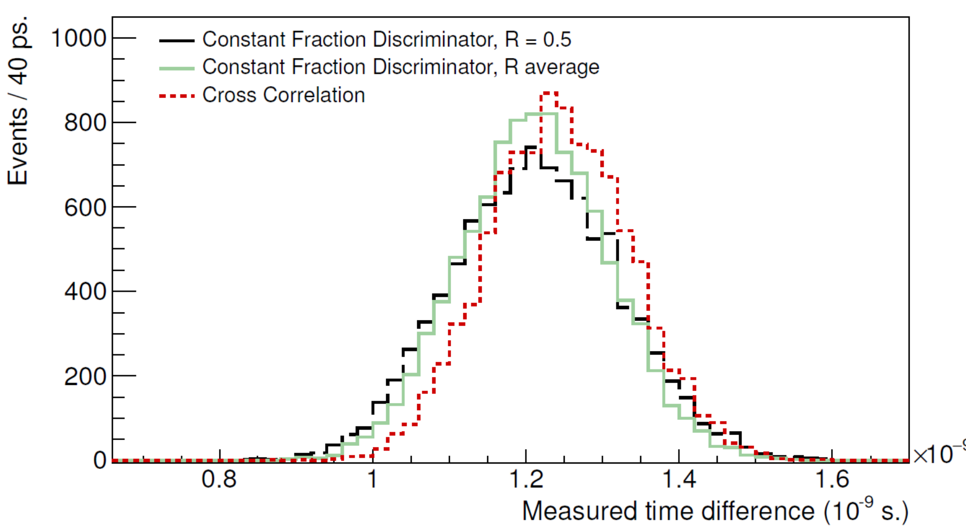
-Sampling Frequency of 6.4 GS/s. Bias voltage of 800 V

-We play on the attenuation of the laser in order to vary signal amplitude




## Signal Shape and Template



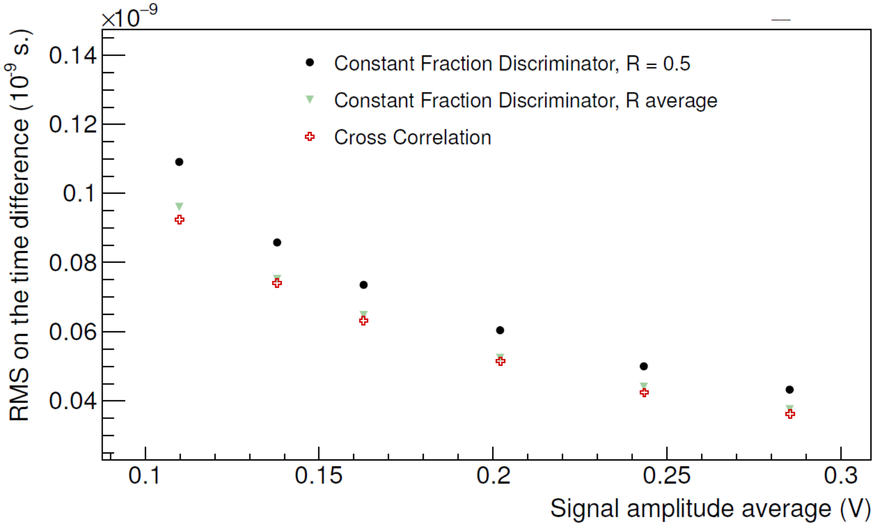



# Results with Laser – Broadband Amplifier – Gain 10 Si

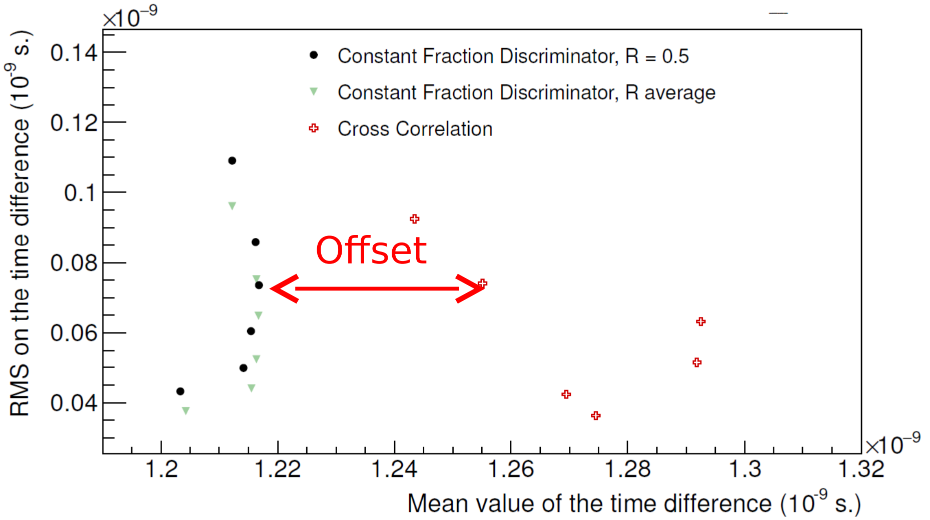
**Performance tests with different amplitudes:**

- Sampling Frequency of 6.4 GS/s
- Performance of CFD with ratios average is equivalent to performance of CC.
- Noticeable improvement of those methods compared to simple CFD (>10 %).
- With 110 mV (~ 2MIPS), resolution of 90 ps, ie 65 ps for each channel

RMS of time differences




Time difference distributions

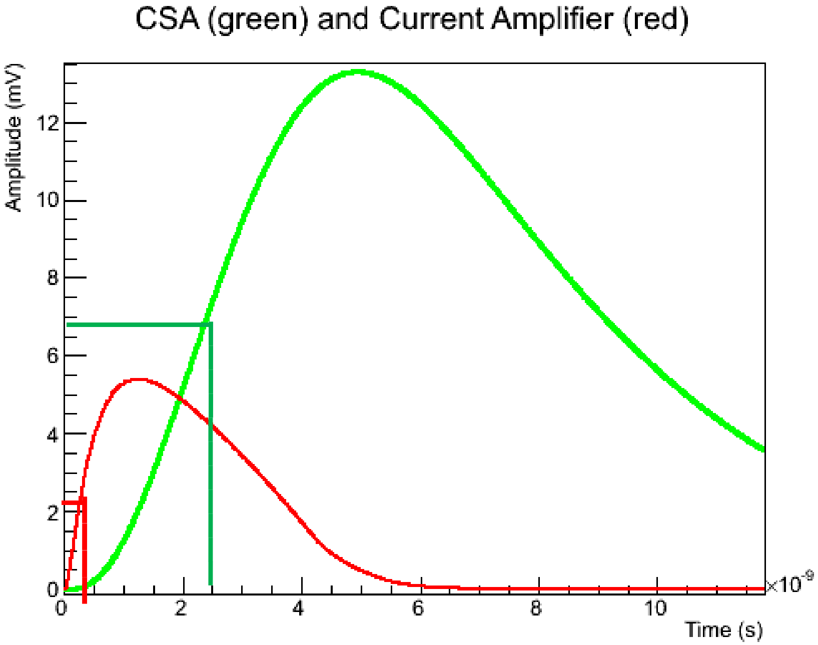


# The Algorithms: Limits

- The offset between the two algorithms can be understood because one algorithm uses a template and the other does not.

- Plot shows that offset can appear between two channels using CFD.

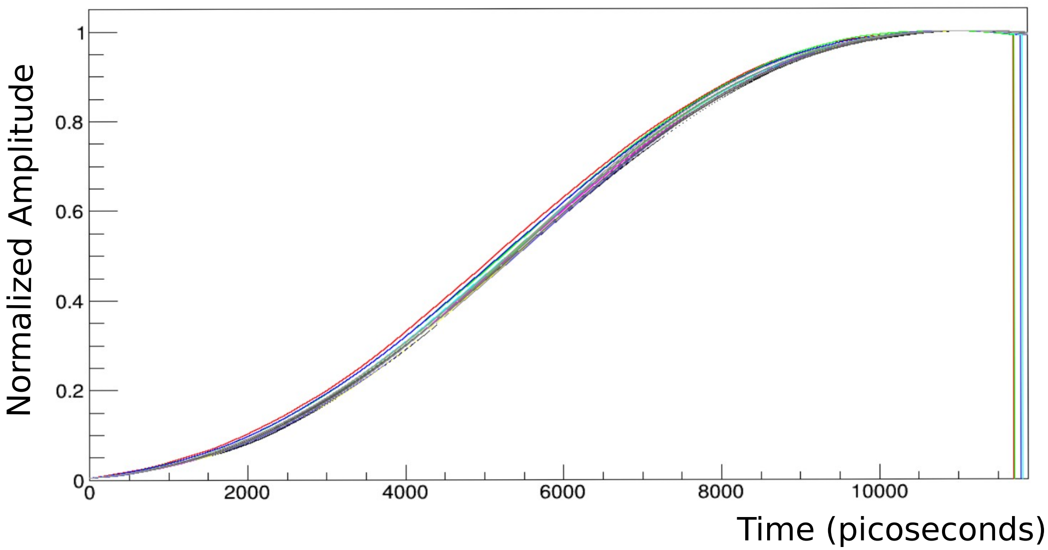
- The offset can be calibrated.




Simulation of gain 10 Silicon Detector, using INFN's software *weightfields*

# Testing SamPic with Laser + Gain 10 + CSA amplifier

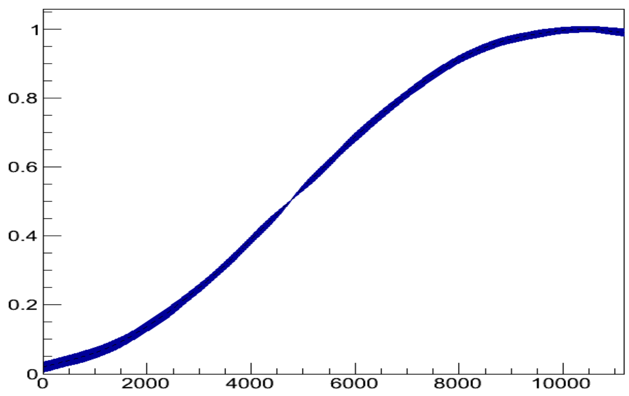
Templates with different tested amplitudes: from 120 mV to 500 mV



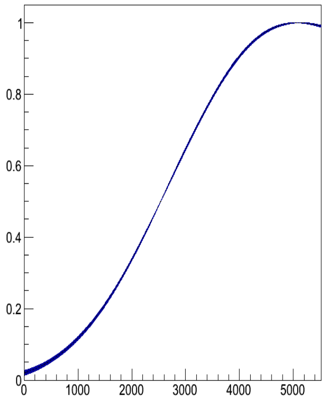

- Shape is perfectly linear with energy.
- One template can be used for a range of energies.
- Using 500 mV template for 120mV signal gives 95 ps RMS.

Cross Correlation for 1 MIP signals

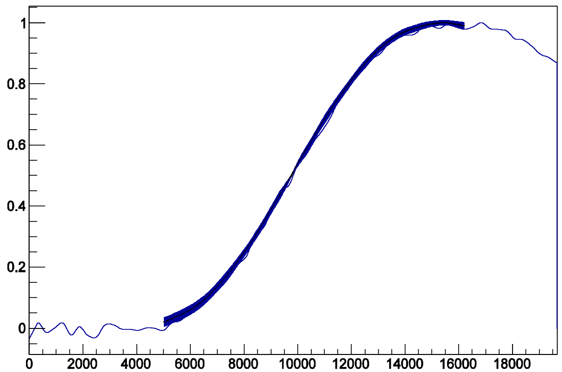
Template of signal Laser 1MIP Gain 10 Si - CSA




Template of Trigger



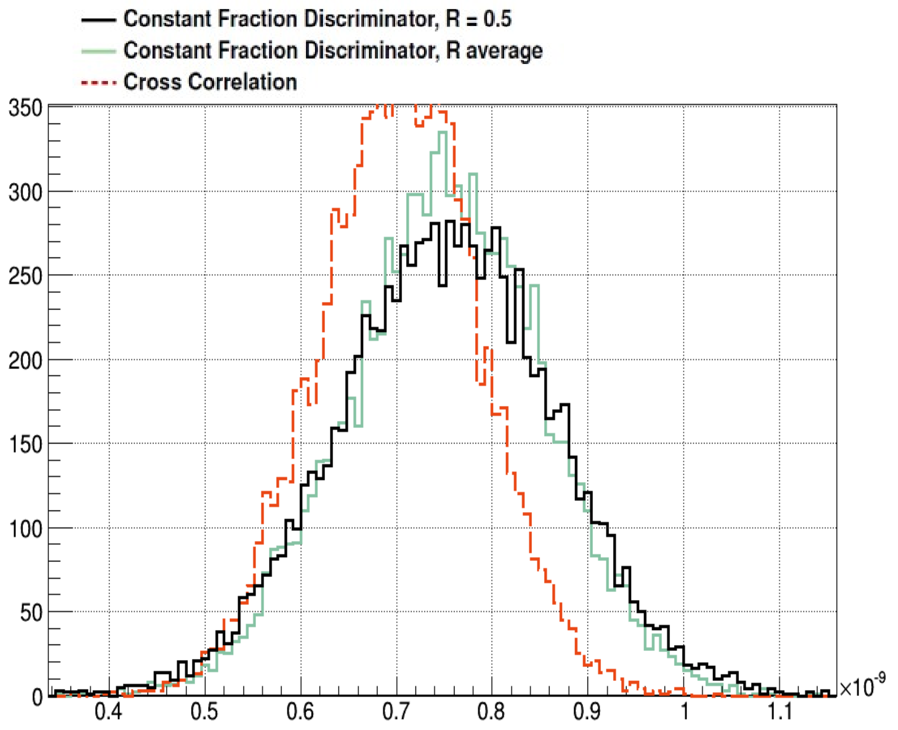

Synchronization between signal and template



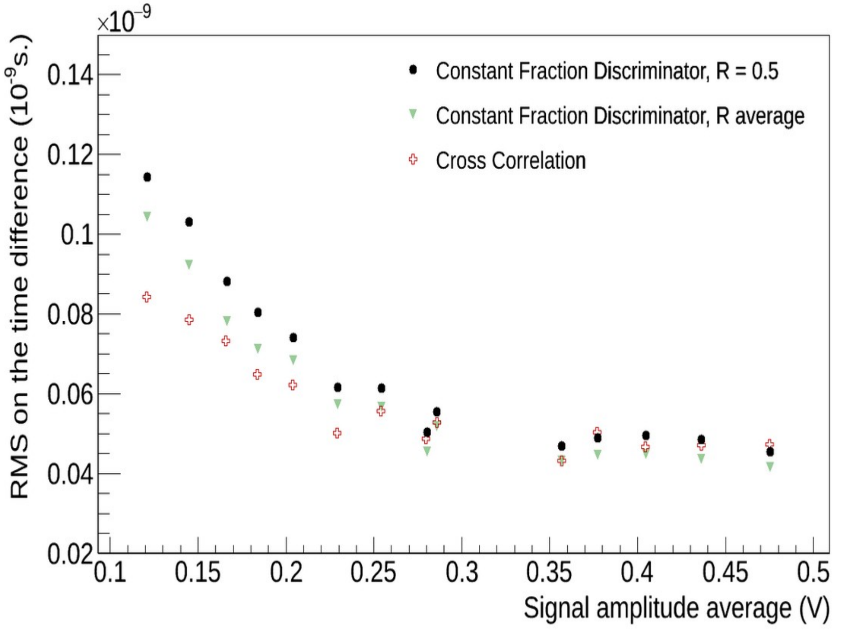
# Performances of SamPic with the Si gain 10

**Particularities:**

- Longer rise time than what has been previously tested.
- Frequency of 3.2 GS/s
- Accurate results for such a long rise-time !

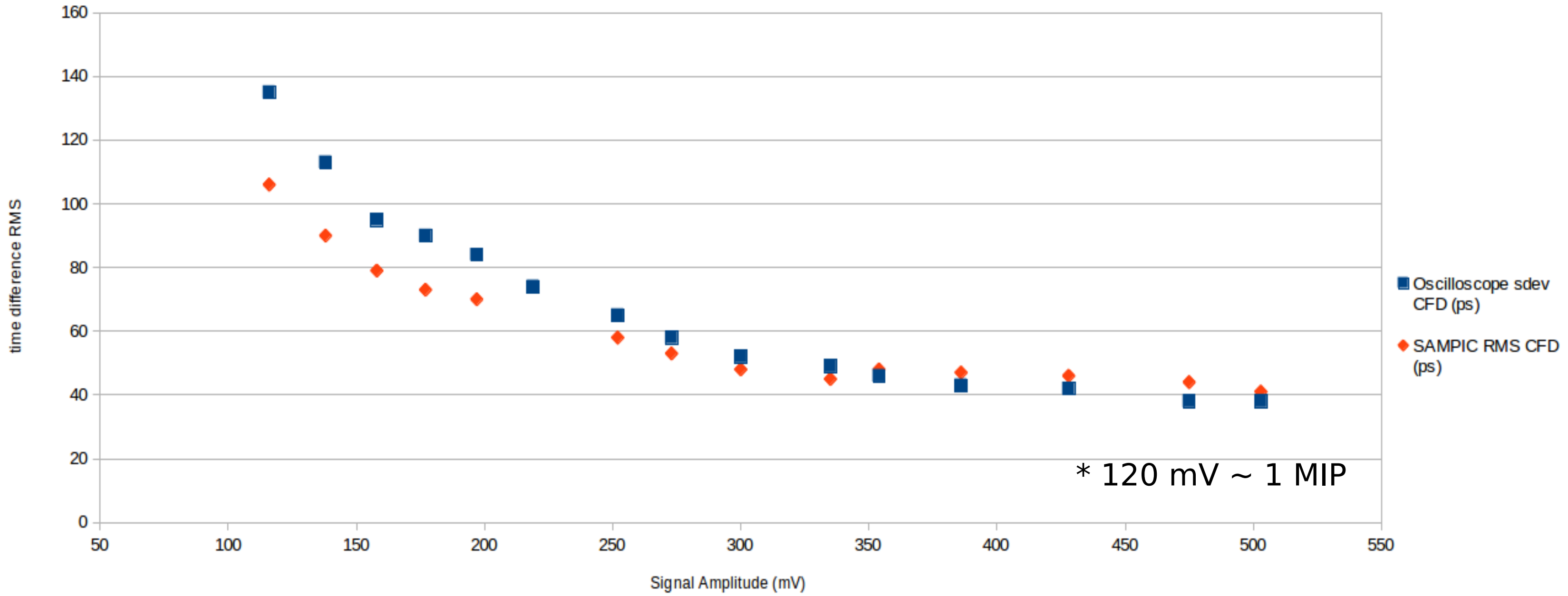



Measured time difference (ns)



# SamPic vs Oscilloscope

CFD with 0.5 ratio: SAMPIC versus Oscilloscope. Gain 10 Si – CSA amplifier




- The difference is most probably due to the digitization (8 bits for the Oscillope – 11 bits for SamPic)

- 11 bits are adequate for low amplitude signals

# Conclusions on the timing measurements

- How to compare time and ensure that our distribution does not suffer any bias ?

➢ No way to know the time difference “a priori”.

➢ Need for a simulation tool in SampicFastAnalysis Software

➢ Complementary with the approach of INFN's weightfields

# Data Simulation module

- Hypothesis :

  - White Noise = Gaussian amplitude for each sample

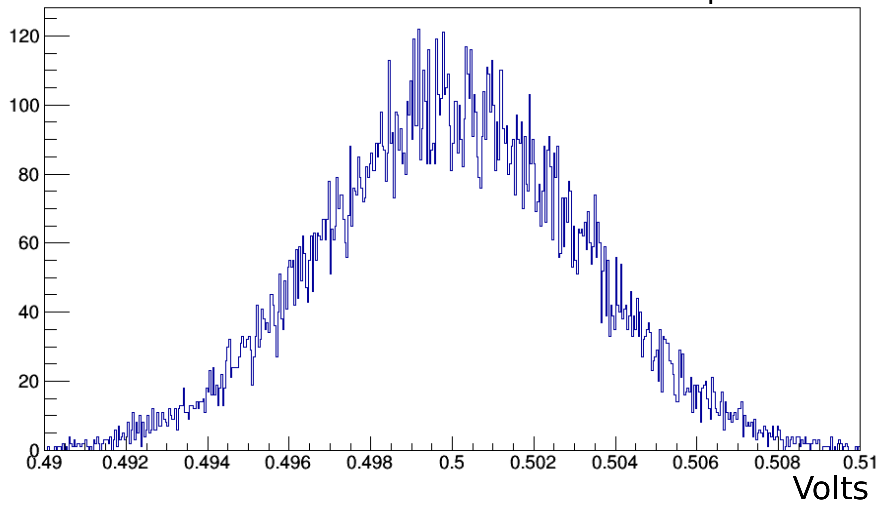
  - No non linearity related error

- Modularity:

  - Possibility to vary signal shape, amplitude, rise-time,  noise type, sampling frequency, etc…

  - Data exported as a root tree of the same format than Sampic Analysis Software

Distribution of calculated baseline with 10 mV amplitude noise



# Conclusion, Current Work & Perspectives

- Conclusion
  - Resolution ~ 3 picoseconds per channel using pure electronics signals
  - For laser tests with 1 MIP intensity, Gain 10 Si and CSA amplifier, resolution ~ 85 picoseconds per channel
  - Showed complementarity between SamPic and UFSD
- Current Work
  - Data simulation module in progress
- Analysis of filtering is necessary to analyze beam test data
  - How to make a selection between signal and noise/bad detections and allow accurate timing in real conditions ?
  - Cross correlation algorithm gives some information about the quality of the time measurement (value of the correlation). How to exploit this information ?
  - Tests with new version of the Online software have to be performed.
  - Characterize optimal sampling frequency versus rise time