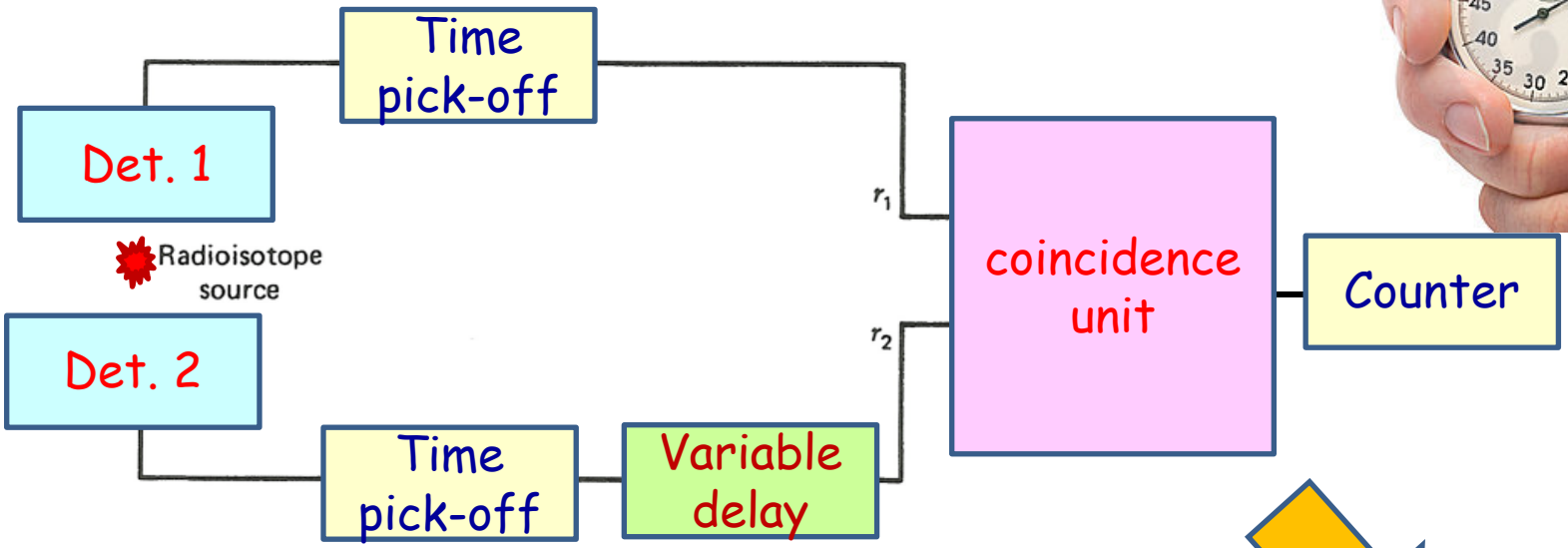
UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Scuola di Scienze
Dipartimento di Fisica ed Astronomia
Corso di Laurea Magistrale in Fisica

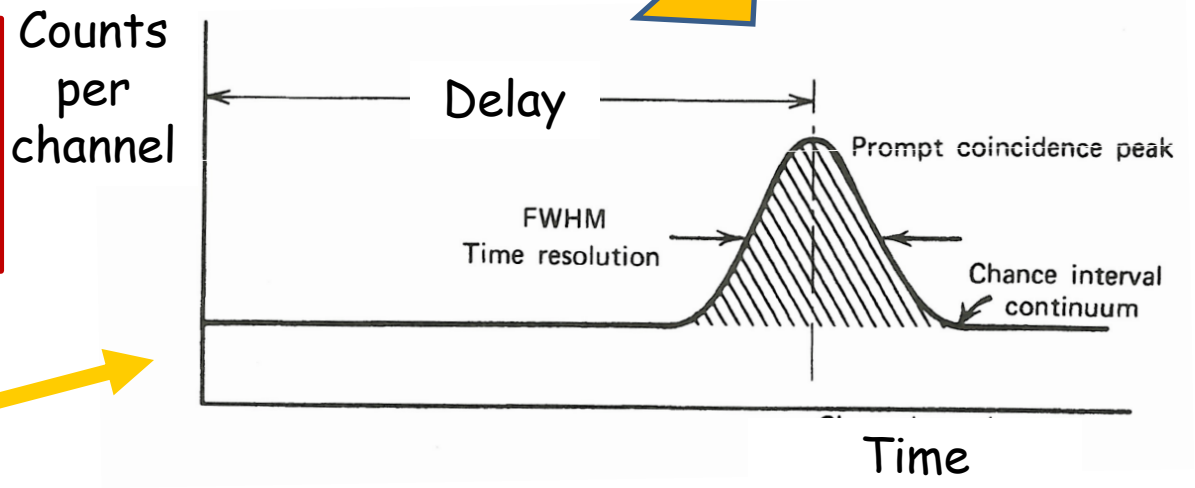
Physics Laboratory

Timing

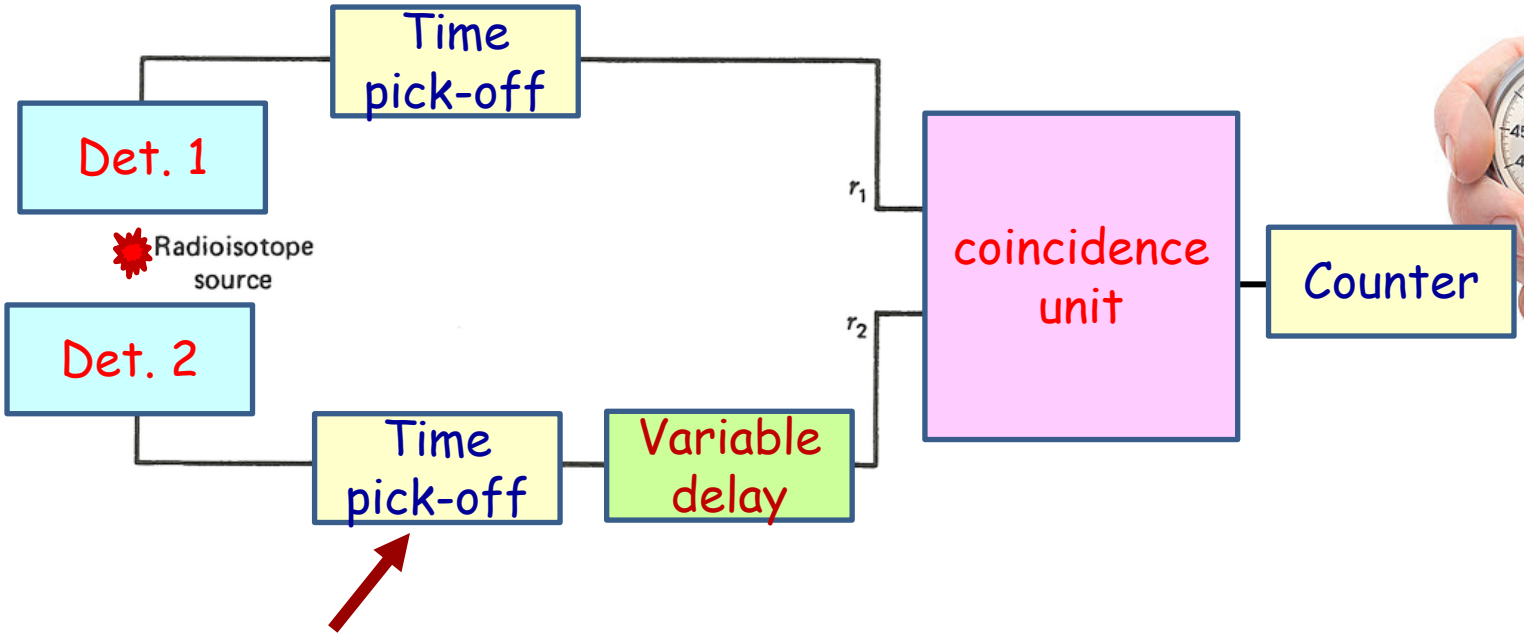
Timing Experiment (timing measurement)



Block diagram for timing measurement between two detector



Temporal spectrum of the coincidences



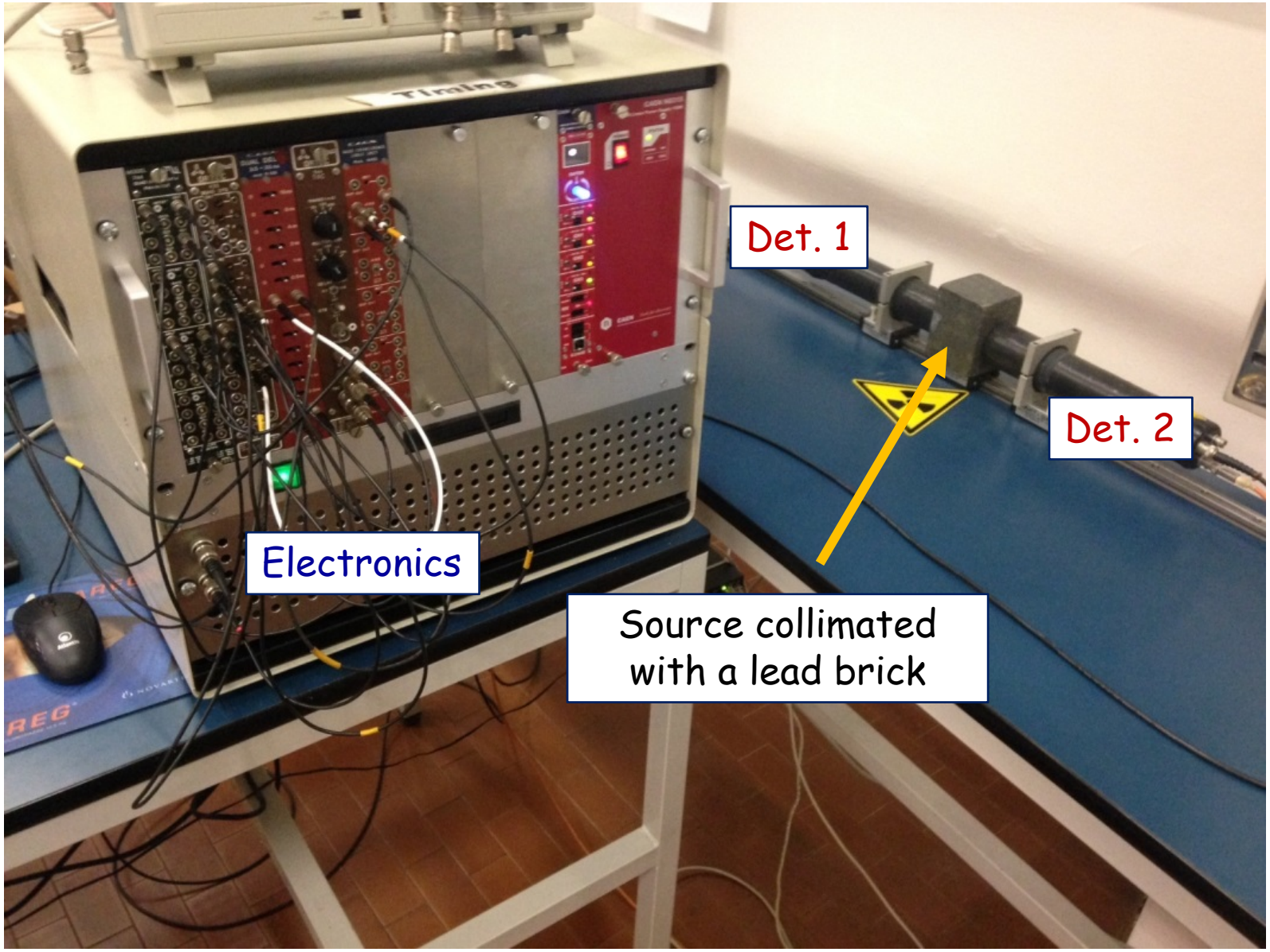
- In this experience the "time pick-off" is a Constant Fraction Timing Discriminator (CFTD). It is used to determine with the minimum uncertainty the arrival time of an event.

- Gamma source of ^{22}Na

- Detector: two cylindrical organic scintillators, EJ-228, with a 5 cm diameter and 5 cm thickness

- The "coincidence unit" could be a Time to Amplitude Converter (TAC)

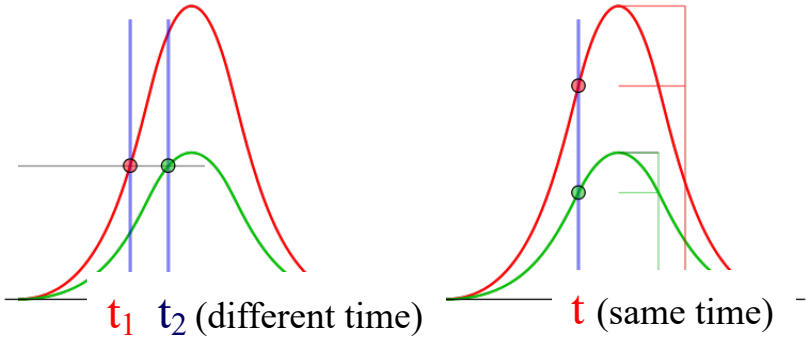
Experimental setup



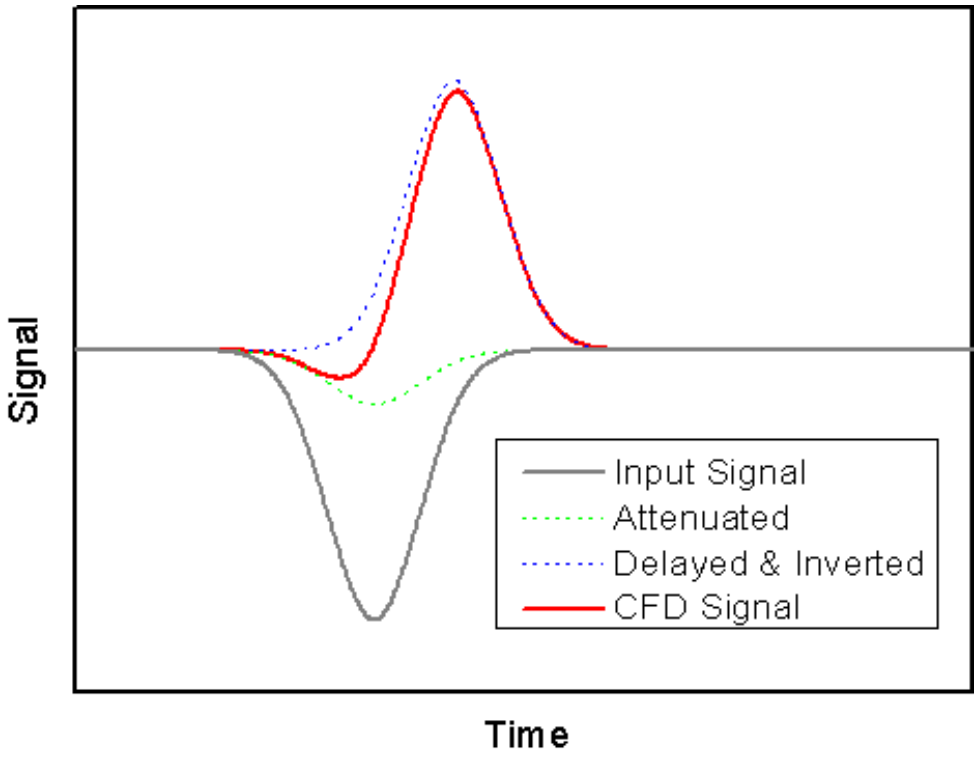
The goal of this experience is to study the accuracy of a time measurement (time resolution) versus a set of parameters of the detector and CFTD

Constant fraction discriminator

The input signal is doubled. The first signal is delayed for a quantity that corresponds to a fixed fraction of the rising time, (usually 80%) while the second signal is inverted and attenuated. The two signals are summed, obtaining the bipolar signal of CFTD.

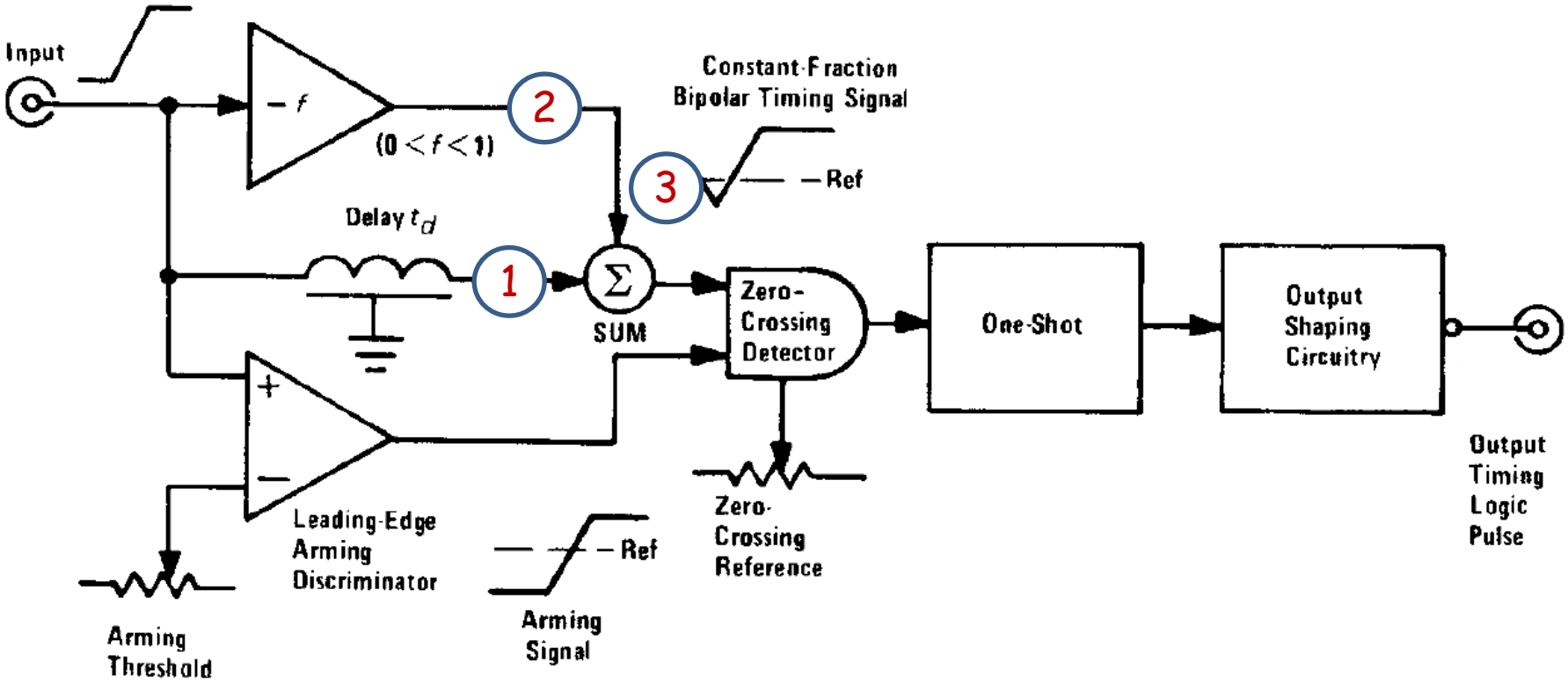


Leading edge CFD

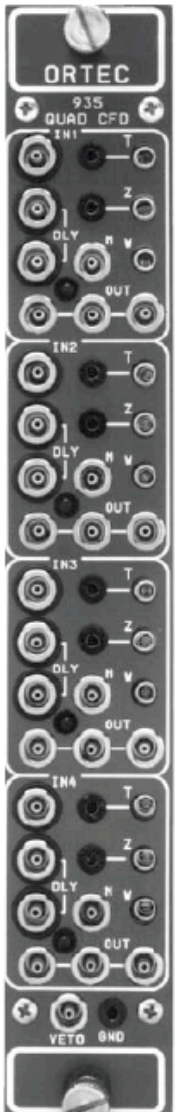


If you select a proper delay in order to align the zero crossing point with the maximum of the original signal, the output of the CFD is independent from the amplitude of the signal. The zero crossing point corresponds to a constant fraction of the rising time of the signal

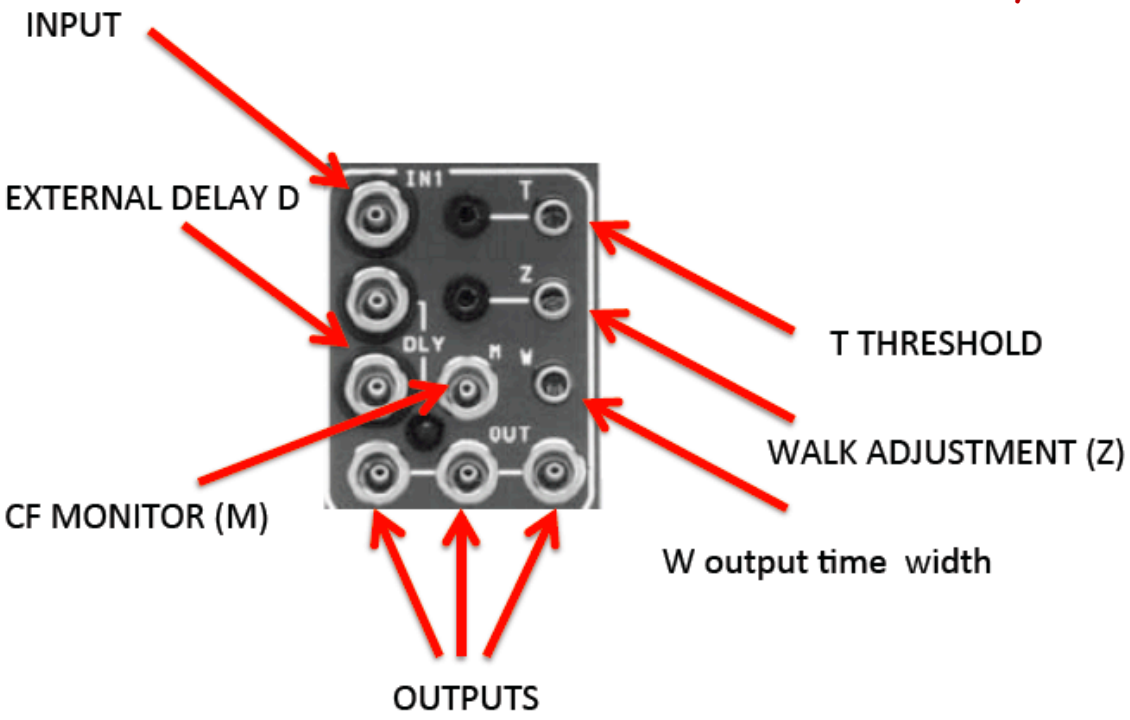
Electronic diagram of a Costant Fraction Discriminator



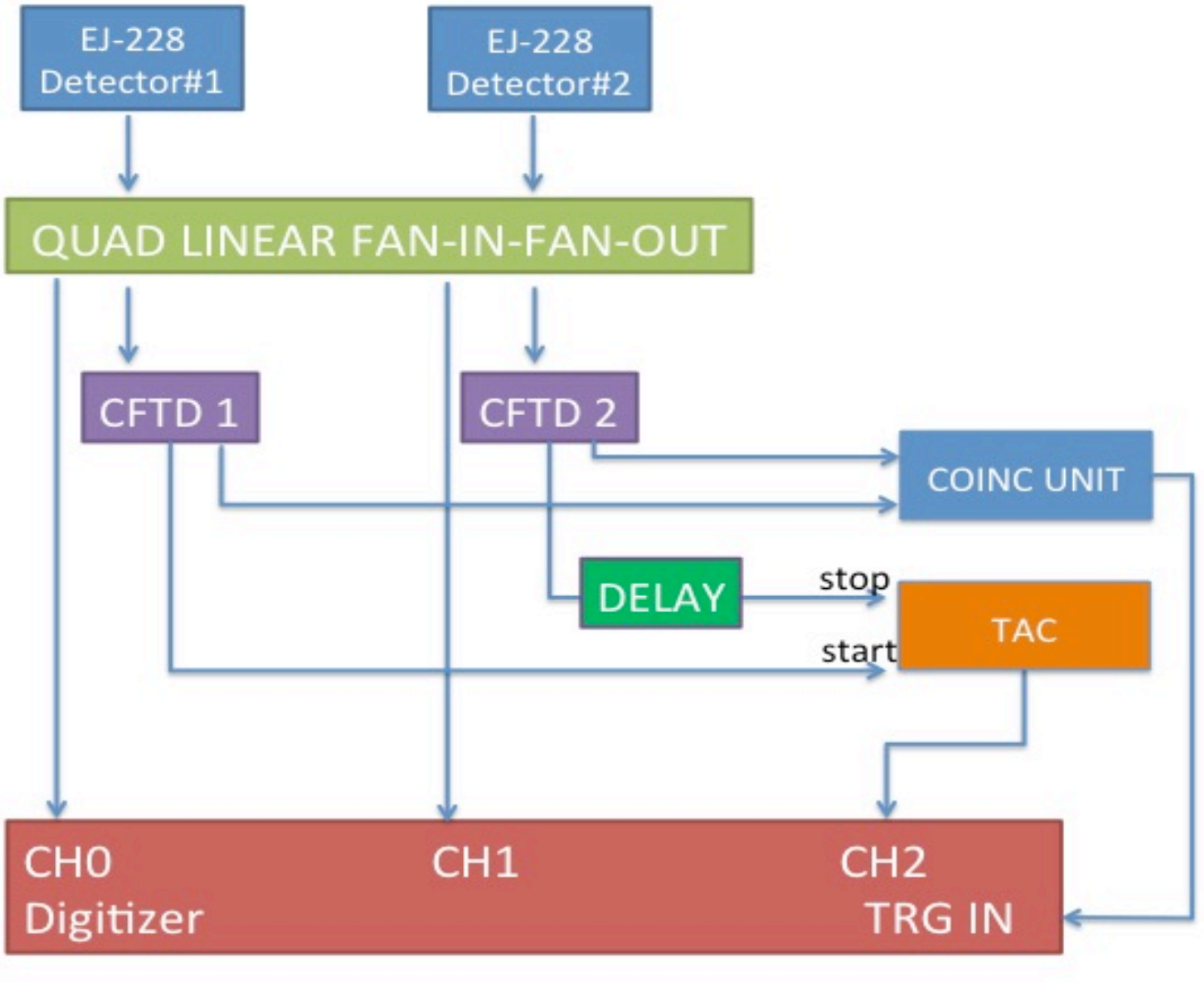
The CFD used in laboratory: mod. 935 Quad 200-MHz CFD



Study of the temporal resolution as a function of a set of parameters that could be set in the CFD (delay, threshold,...)



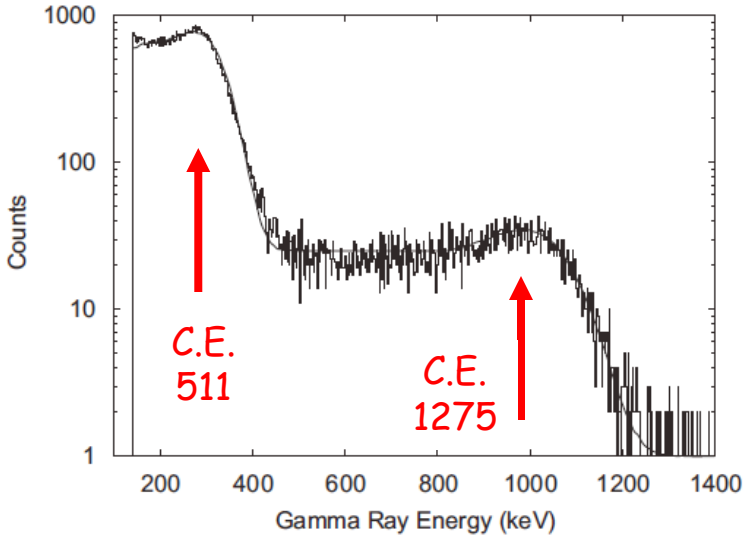
Schematics of the electronics



The organic scintillators contain only light elements like C and H and the photo-electric cross section is negligible for the energy used in laboratory (511 and 1275 keV). Furthermore, the probability of total absorption of the total energy of gamma-ray through multiple Compton Scattering are negligible, due the small size of the detector. Therefore the response function of the detectors will be dominated by the individual Compton interaction, the result is a continuous distribution that corresponds to different angles of interaction, with a "Compton Edge" at the maximum energy kinematically allowed

The nominal energy of Compton Edge (C.E.) can be calculated as follow:

$$E_{CE} = \frac{2E^2}{m_e c^2 + 2E}$$



The real position depends on the energy resolution of the detector

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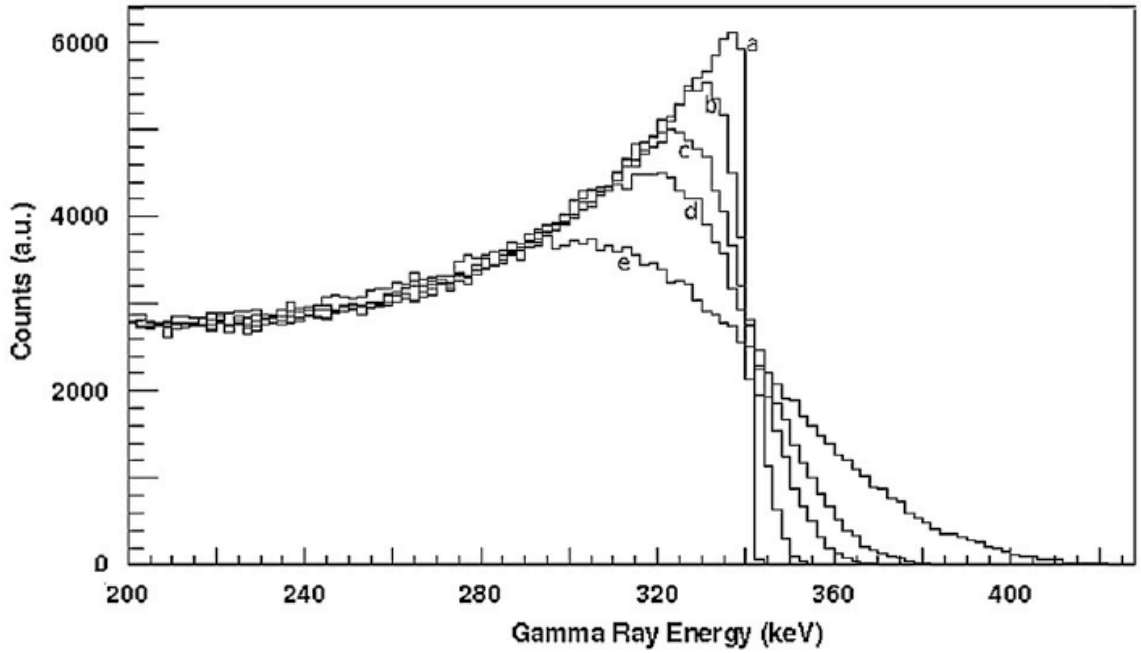
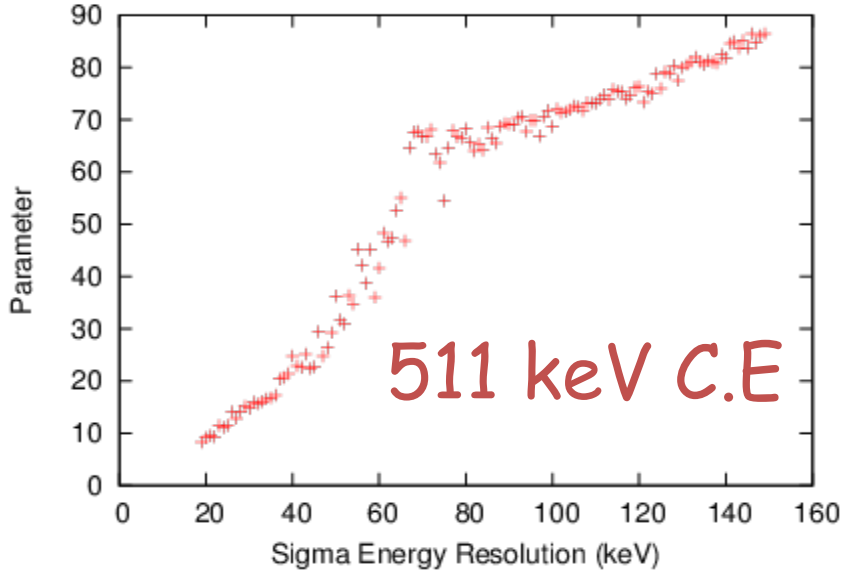
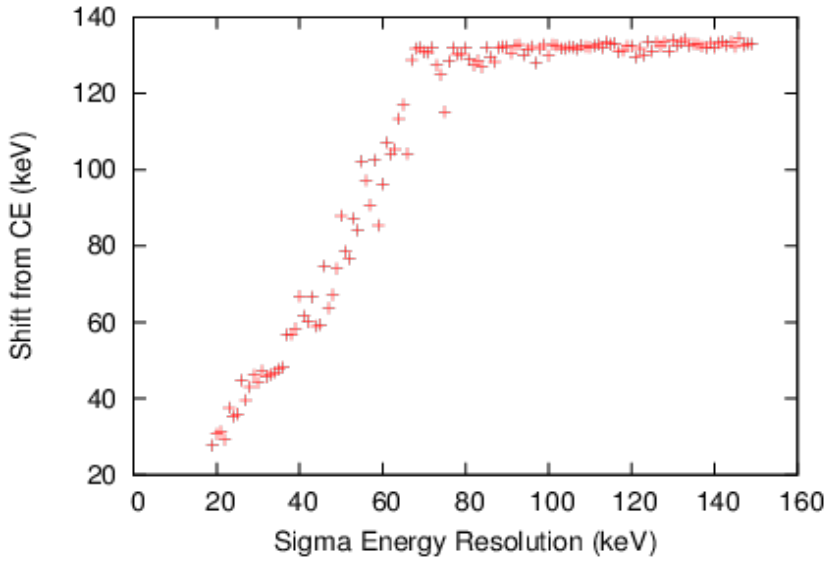
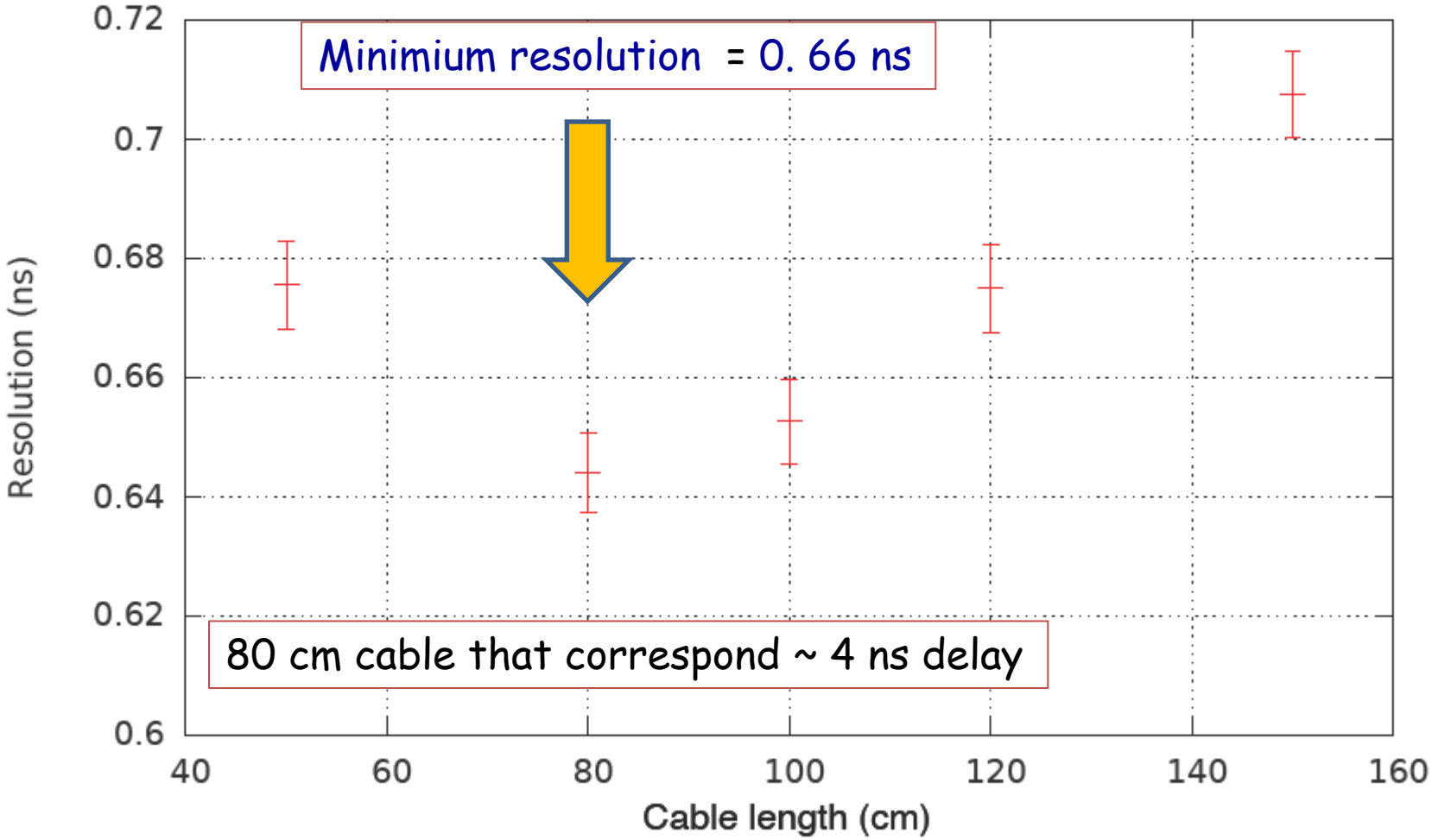


Computed distributions of the Compton scattered events without (a) and with different Gaussian smearing corresponding to 5 (b), 10 (c), 15 (d) and 25 (e) keV pulse resolution

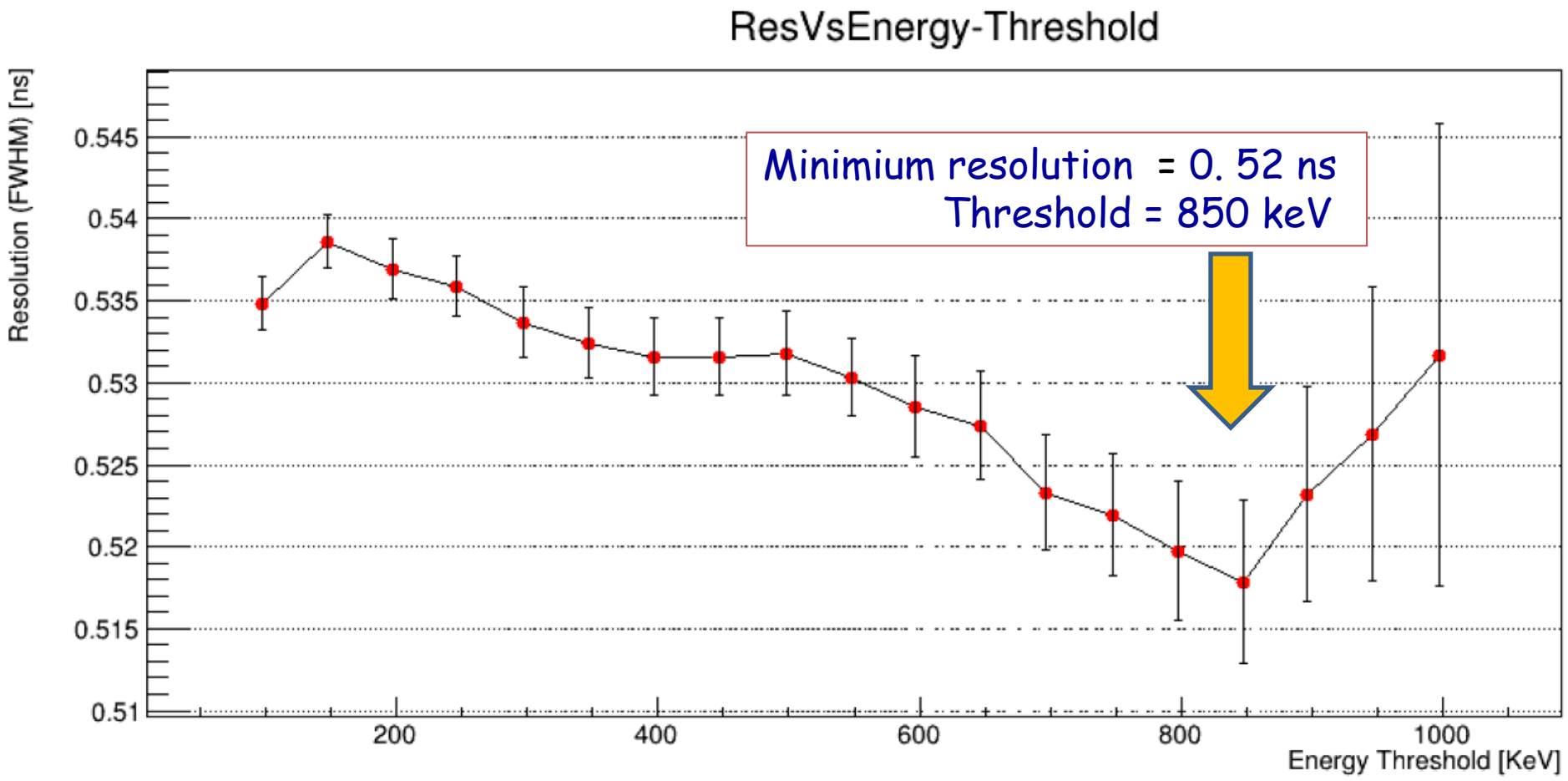




Example: time resolution as a function of the external delay of CFD



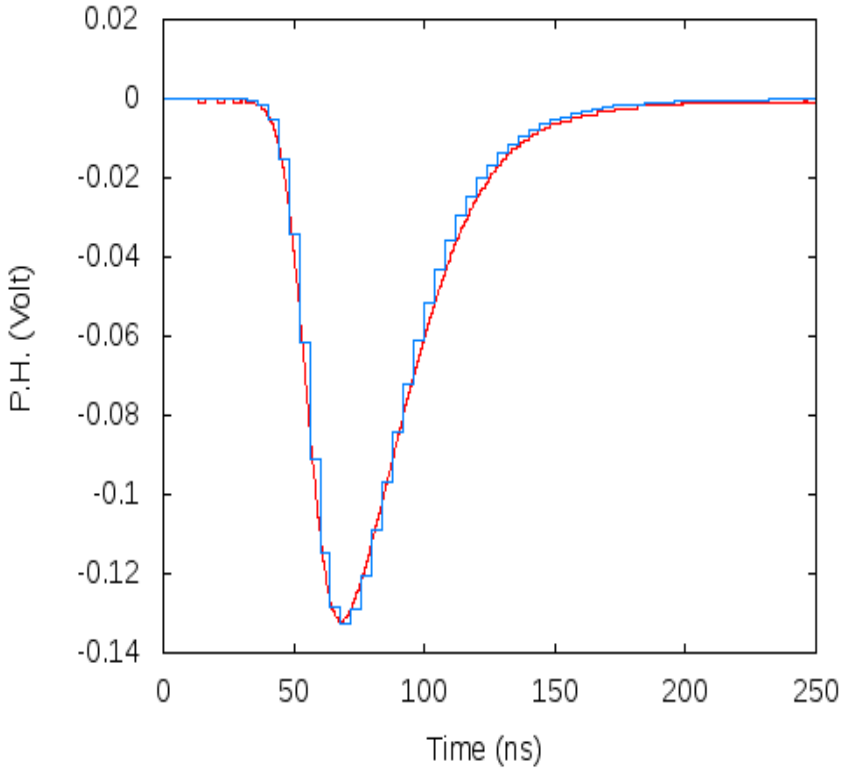
Example: time resolution as a function of the Energy



Digitizer acquisition for offline CFD software reconstruction

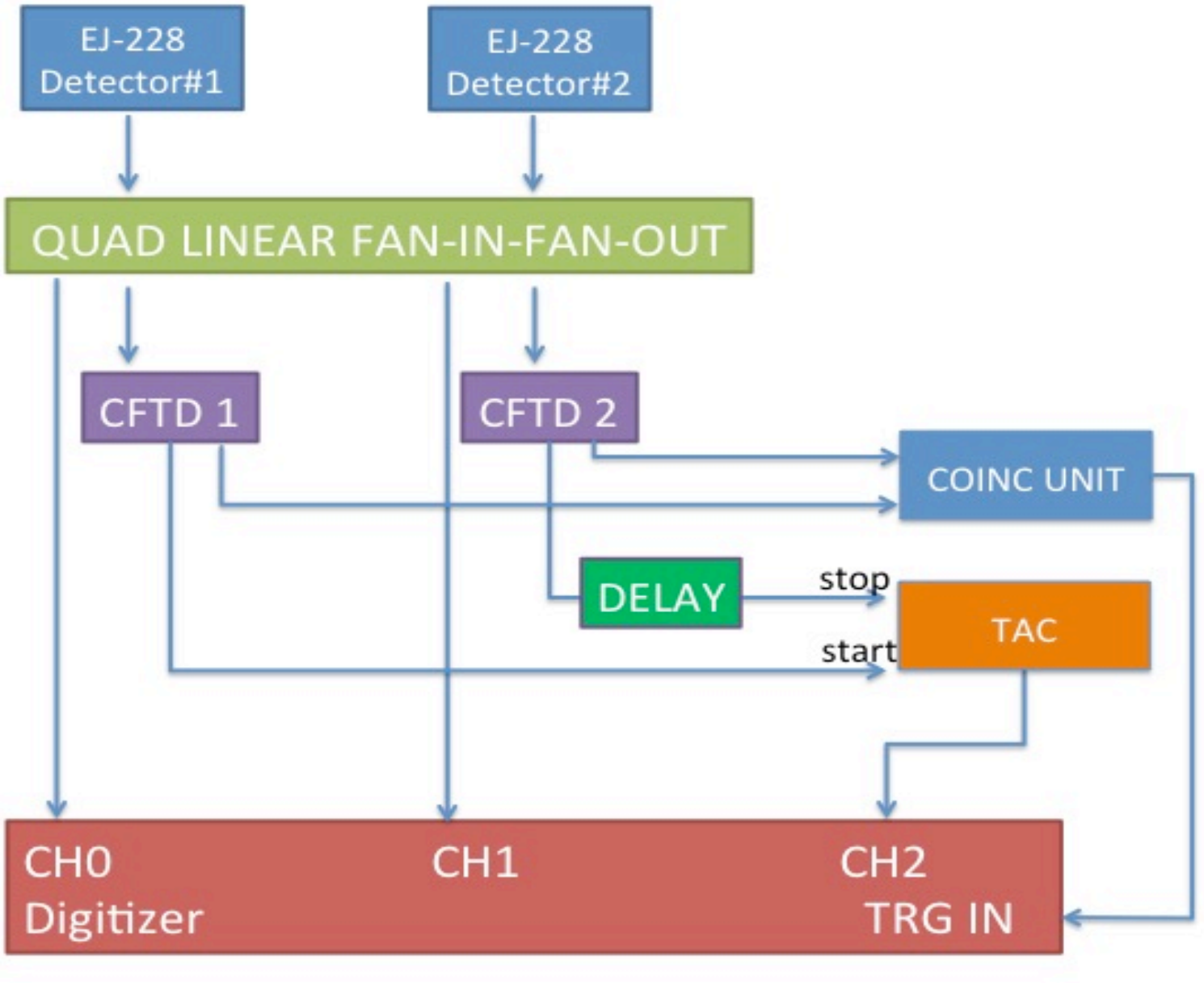
You will use a 1 Gs/s digitizer, with resolution of 10 bits.

Timestamp of each events is in NS.

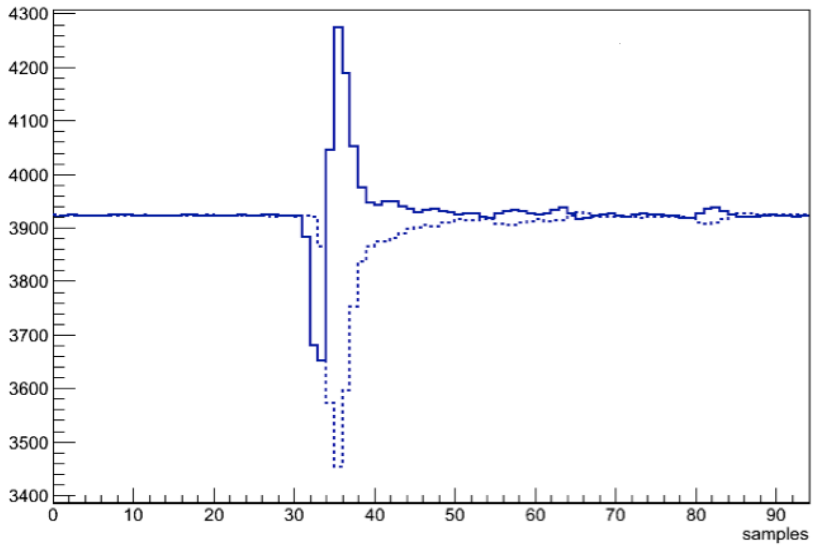


You will acquire waveforms like the one on the left, together with timestamps and energy information.

Schematics of the electronics

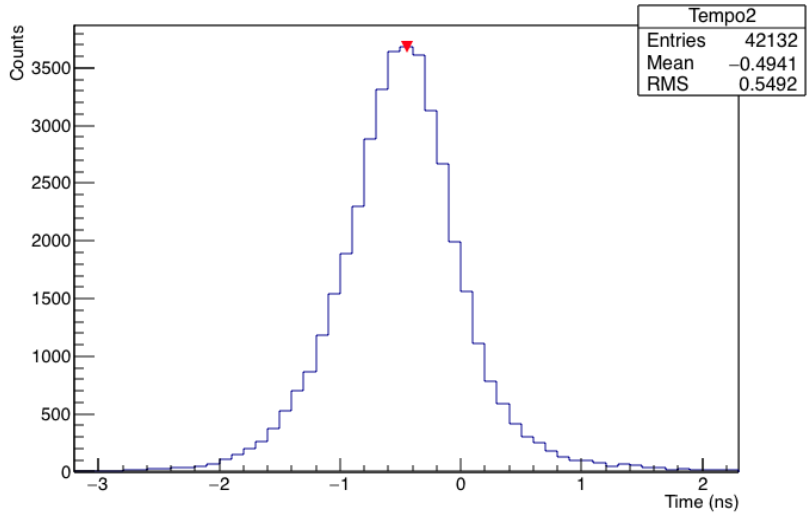


How to build a software CFD



Offline analysis: We will provide to you a ROOT macro as an example. Such macro needs to be modified.
The resolution can be studied by:

- Energy selection
- Attenuation
- Delay
- Baseline estimation



Goal:
- what is the best resolution obtainable?
- Comparison between the results obtained by analog and digital treatment of the signals

Measurement of the speed of light

You will use the parameters estimated as the best one during the previous part of the experience in order to obtain the best possible measurement of the speed of light.
Collect 2 datasets with the source in different positions, so that the time-of-flight of the photons will change.
Notice: the time of flight change for both the photons.

1)

2)

In summary, the goals of the timing experience are:

- Energy calibration of the organic scintillators and calculation of the energy resolution from the analysis of the Compton edge
- Optimization of the external delay of the analogue CFTD to obtain the best time resolution
- Study the time resolution behaviour as a function of the energy
- Comparison between the timing resolutions obtained from analogue and digital treatment of the signals
- Measurement of the speed of light