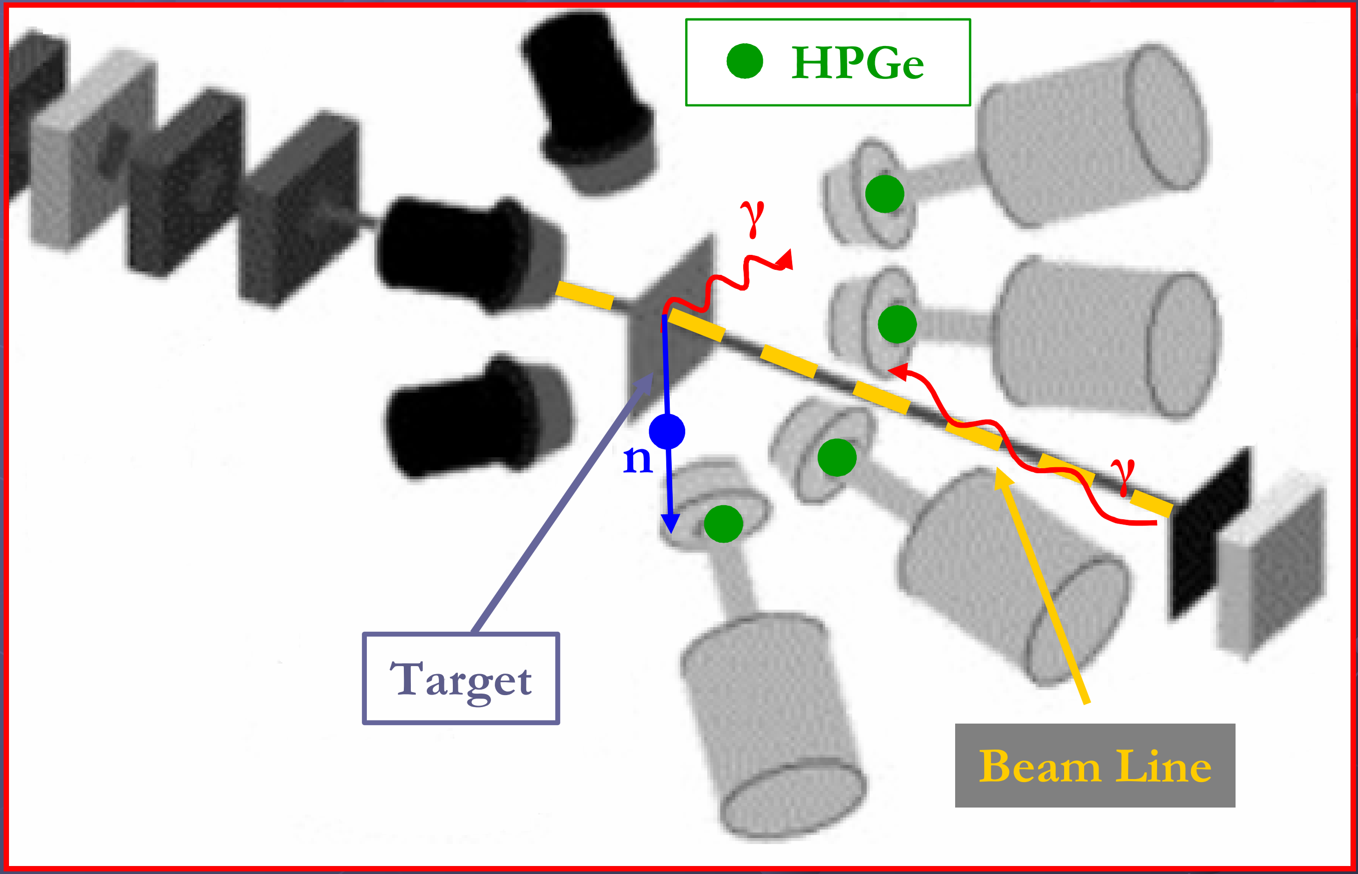
Improvement of HPGe Detectors Timing Using Pulse Shape Analysis

FABIO CRESPI - University of MILANO / INFN MILANO

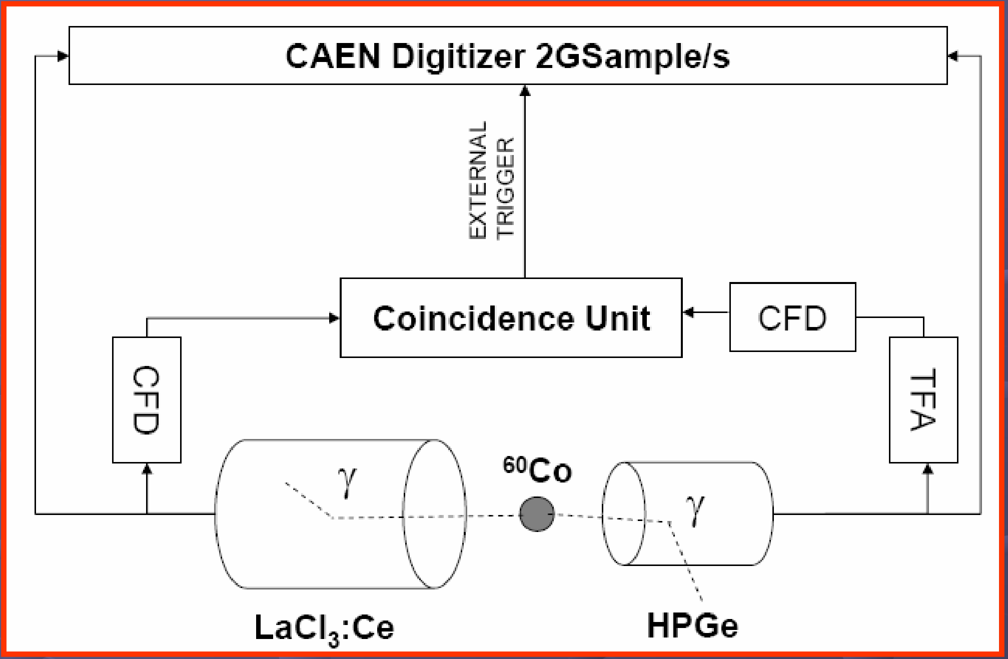
In-beam Gamma Spectroscopy Experiments

In this kind of experiments a **precise time information is extremely important**, for instance: in heavy-ion fusion-evaporation experiments (**to discriminate the unwanted contribution of neutrons by time of flight measurements**) or in experiments with radioactive ion beams (**to suppress the background radiation not coming from the target position**).



HPGe Detector Signals Acquisition

The aim is to acquire time aligned HPGe detector signals for testing the PSA algorithms



- ^{60}Co source (1173 keV,1332 keV) is placed between the detectors: a **coaxial P-type HPGe** Tennelec model CPVDS30-10195 with 3000 V bias voltage and a **LaCl3:Ce crystal, cylindrically shaped**, with a diameter of 4″ and 6″ length, coupled with a photomultiplier Photonis XP3540B02.

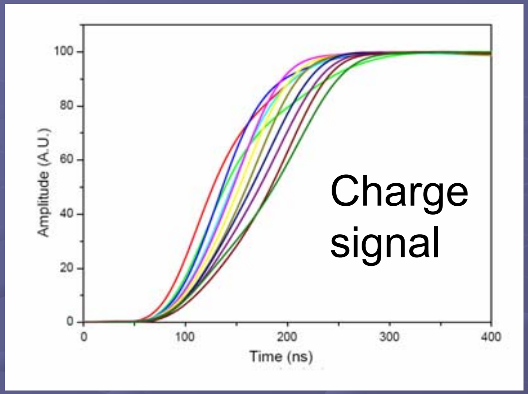
- The signal shapes of both detectors **digitized at 2 GHz in a time window of 1 us**, using a 12 bit CAEN V1729 ADC VME board

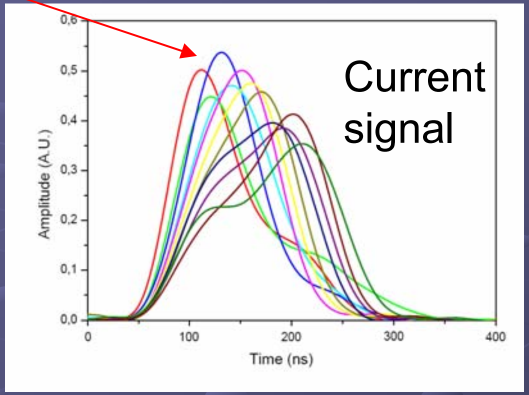
- Energy threshold of the LaCl3:Ce CFD set just below 1332 keV.
(**only the events in which the lower energy gamma (1173 keV) has interacted in the HPGe** detector and the higher energy one (1332 keV) in the LaCl3:Ce have been selected)

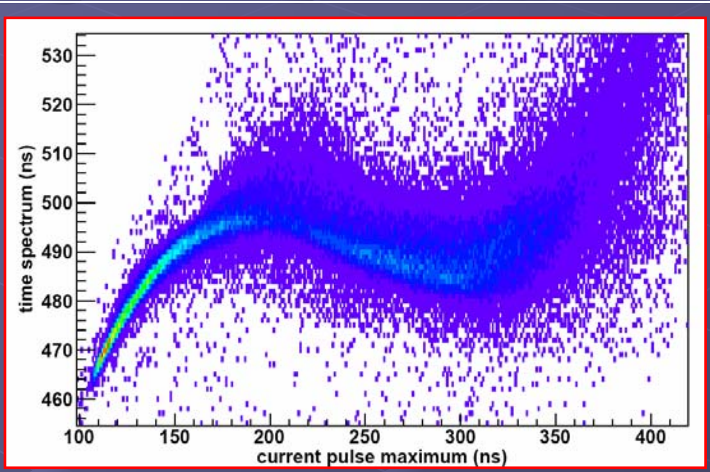
CFD timing

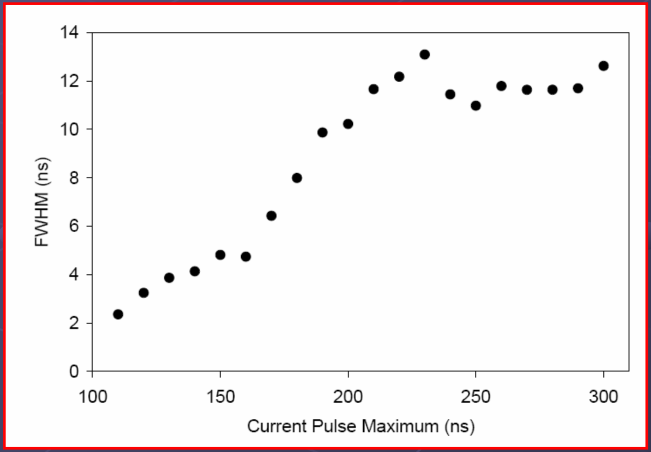
CFD output dependence on the signal shape

the **position of the current signal maximum** effectively defines the signal shape



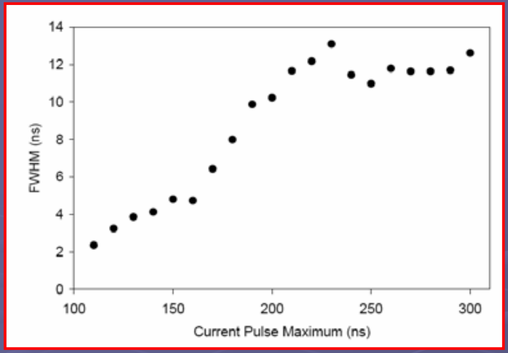


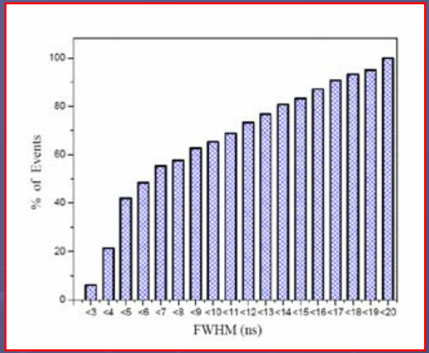




- CFD parameters are *d* = 90 ns; *fi* = 150 MHz; *fd* = 5 MHz; *A* = 0.25 (not optimized!)
- These parameters values enhance the dependence of time information on the signal shape
- Not only the centroid of the CFD time distribution changes with the shape of the signals but also its FWHM (i.e. the time resolution).

CFD timing

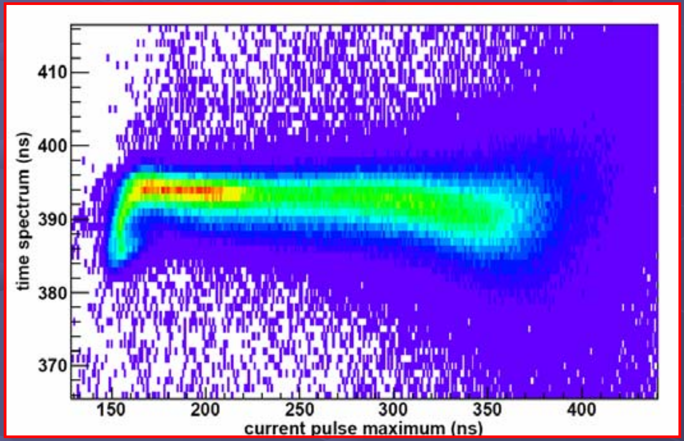


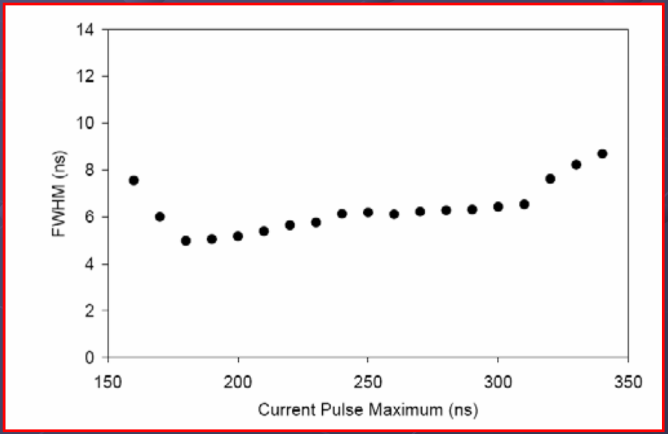


❑ In the range [100 ns ,230 ns] the time resolution is directly proportional to the distance between the signal starting and the current pulse maximum

❑ Percentage of signal shapes with a time resolution under a certain threshold:

→ **about the 8% of the total events have a time resolution of less than 3 ns!**





❑ Optimized CFD parameters: *d* = 34 ns; *fi* = 100 MHz; *fd* = 5 MHz; *A* = 0.25

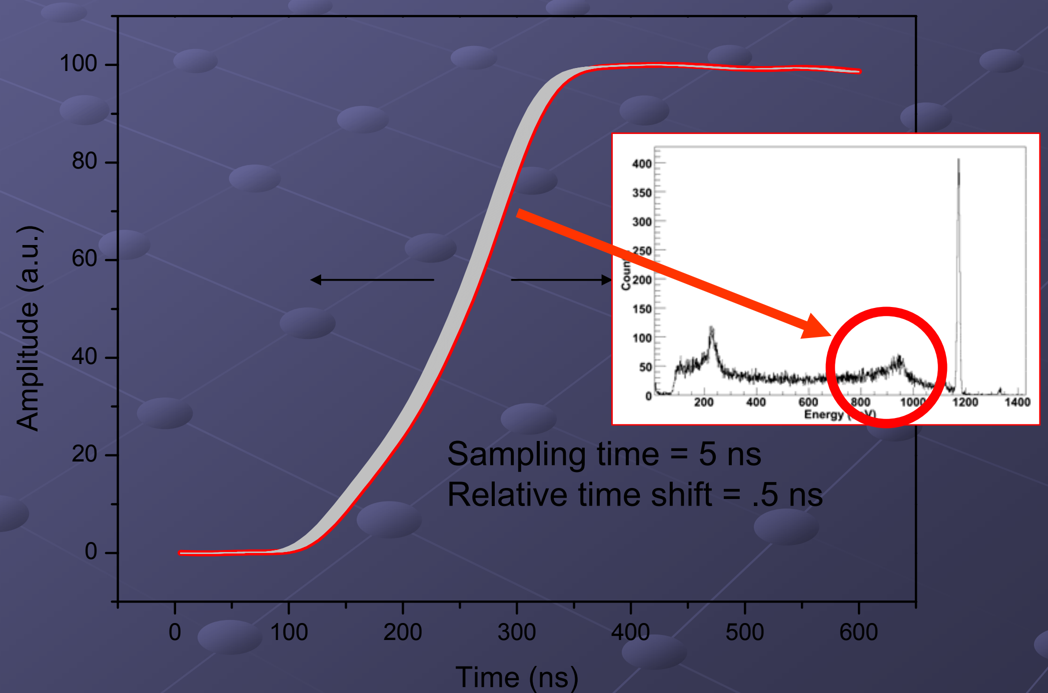
The optimization procedure of the CFD parameters gave the same time resolution (i.e. ~ 8 ns) as performing the correction of the CFD output depending on the current pulse maximum position, without optimized parameters!

Timing using PSA algorithms

BASIC IDEA: extract the **time information by comparing the detector signal and a set of reference signals** (signal basis). The signal basis contains all the possible signal shapes produced by the detector following a single interaction event and their **time shifted copies**.

Experimental extraction of the signal basis:

- We need to select a set of signals associated to single interaction events and spatially distributed in such a way to cover the whole detector volume.
- We chose to include in the basis 30 time shifted copies for each signal. The relative time shift from one copy to the next is 0.5 ns, thus covering a 15 ns interval.



Timing using PSA algorithms

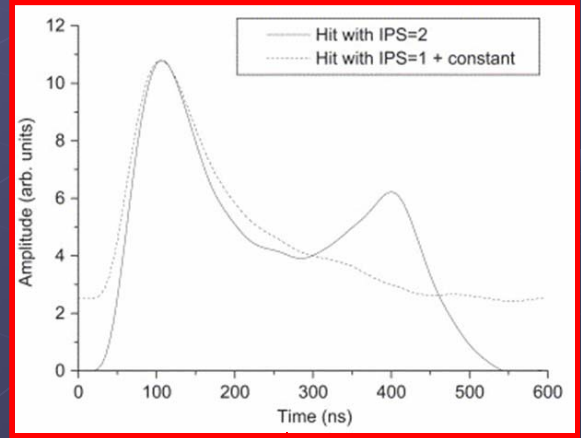
Single interaction events case (Compton Edge)

- the detector signal shape is already present in the basis: performing a χ^2 comparison between the input signal and the elements of the basis allows to select the shape that is more similar and this in turn determines the time information (i. e. the time shift of the selected element)

Considered not simply the time shift of the best χ^2 element of the basis but also the one given by the average of the time shifts associated to the **"N" best elements**.

N	FWHM (ns)
1	9,0
5	5,0
10	4,4
15	4,2
20	4,0
30	3,6
45	3,4
60	3,2
150	2,8

RS algorithm (F.C.L. Crespi et al. NIMA 570 (2007) p.459 and F.C.L. Crespi et al. NIMA 604 (2009) p.604)



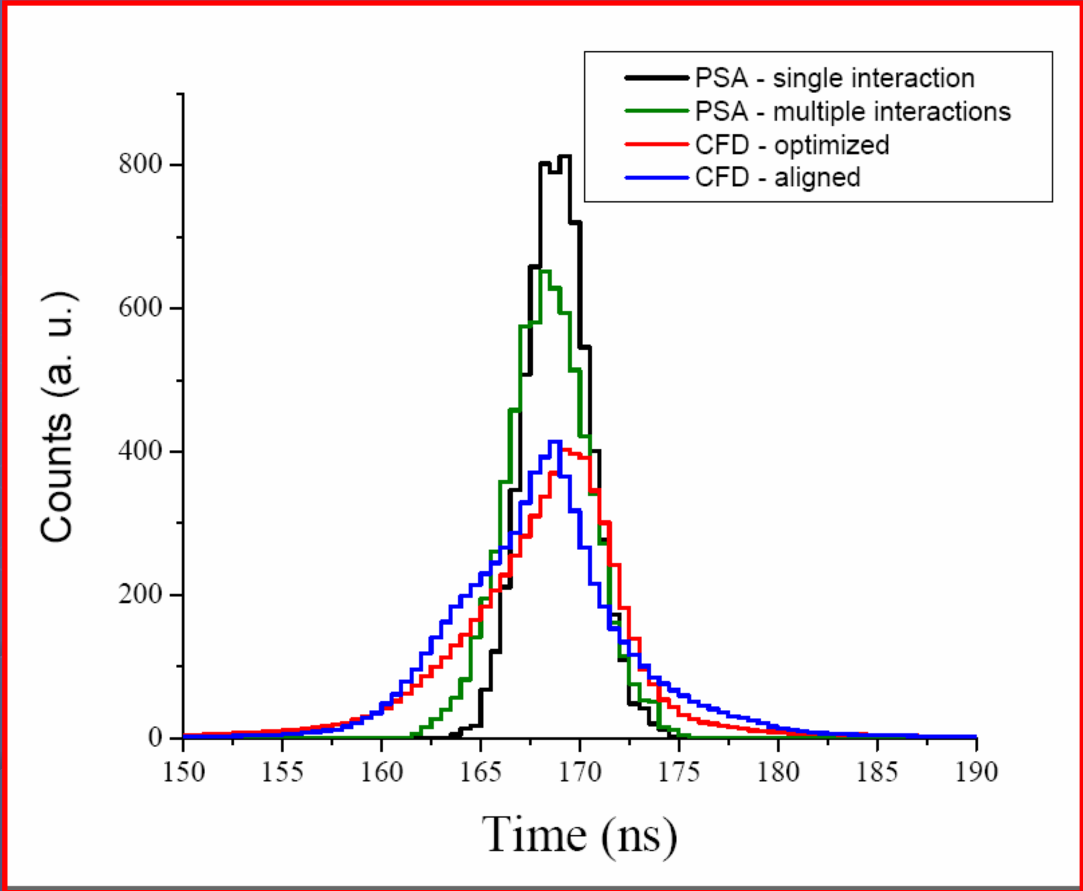
Multiple interaction events case (1172 keV FEP)

- The detector signal is a **linear combination of the basis elements**.

→ As a consequence a **PSA algorithm is needed to decompose the input signal in the element of the basis.**

We chose for the application of the method a value of N = 60, as a compromise between the time resolution and the amount of computing power needed to process one event

Timing using PSA algorithms



Improvement in time resolution obtained applying RS algorithm:

3.2 ns FWHM for the single interaction case (black line histogram)

4.2 ns FWHM for multiple interactions (green line histogram)

Blue and red line histograms represent the results of a **standard CFD** with optimized coefficients (**red line histogram, 7.6 FWHM**) and with the centroid positions aligned (**blue line histogram, 8.2 ns FWHM**)

Conclusions and perspectives:

- The dependence of CFD output on the signal shape showed that the **time resolution can range from 2 to 12 ns**, depending on how fast the signal is in the very first part of its rising front
  - A subset of data with time resolution of 2-3 ns can be achieved using a standard CFD and exploiting the information of the rise time of the signal: extremely useful in in-beam gamma spectroscopy experiments to understand the structure of the time spectra with high resolution, for the optimization of the time gates.

- **A time resolution of ~ 4 ns has been achieved applying a PSA algorithm to HPGe signals.**
  - In the case HPGe signals are digitized and stored, an offline analysis using PSA-RS algorithm will permit to reach a time resolution of 4 ns

- **Application of the method developed to large volume segmented HPGe detectors**