PULSE SHAPE COMPARISON FOR HPGe DETECTORS WITH THE WILCOXON SIGNED-BASED TEST

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1. Introduction
2. Characterization of HPGe detectors
3. Wilcoxon rank-based test
4. Comparison with χ^2
5. Conclusion

CONTENTS

Introduction

Electric signals in HPGe detector

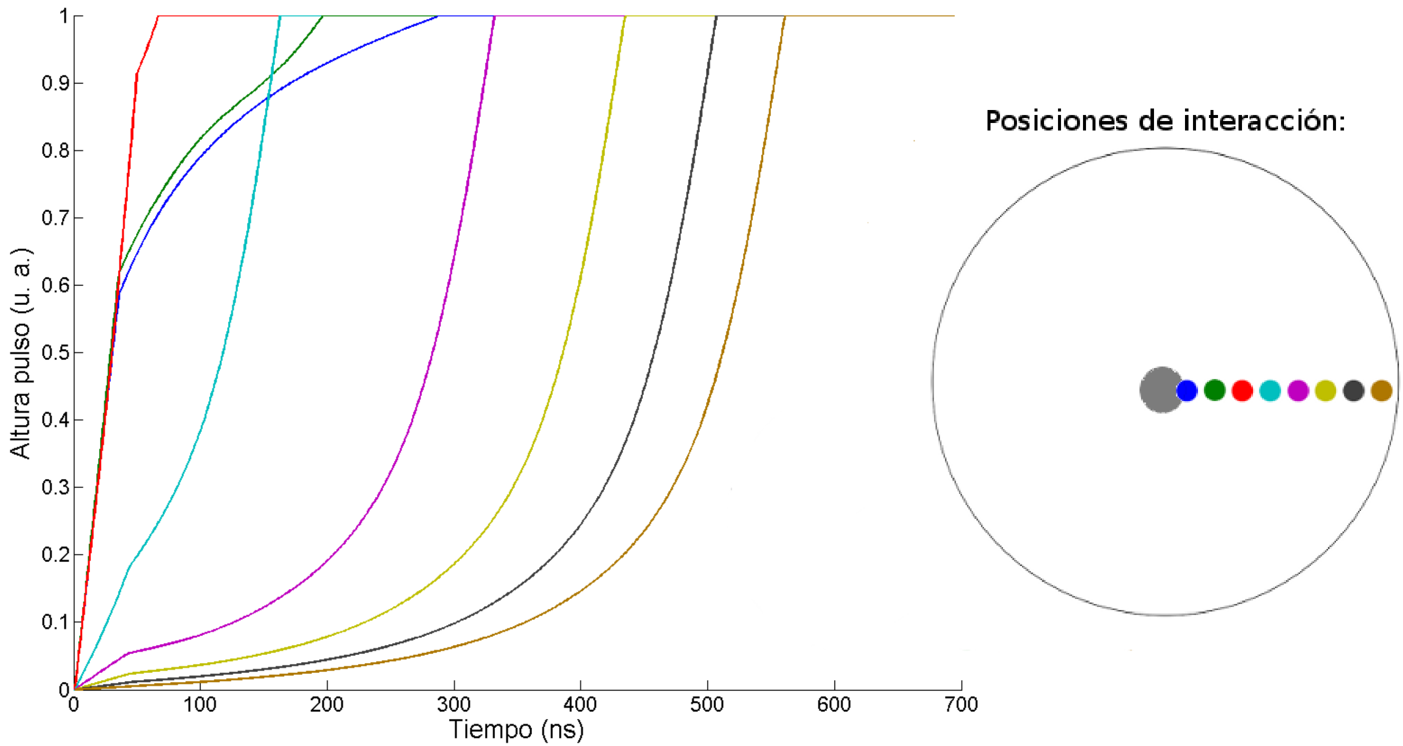
- The measured signal depends critically on:
  - Crystal and contacts geometry
  - Interaction point of the radiation inside the crystal
  - Electronic amplification phase

- Pulse shape comparison (PSC) method is needed in the process to associate signal shapes and positions inside the crystal.

Characterization of HPGe detectors

HPGe characterization

- The pulse shape depends on the position interaction of the radiation.



SALSA characterization system

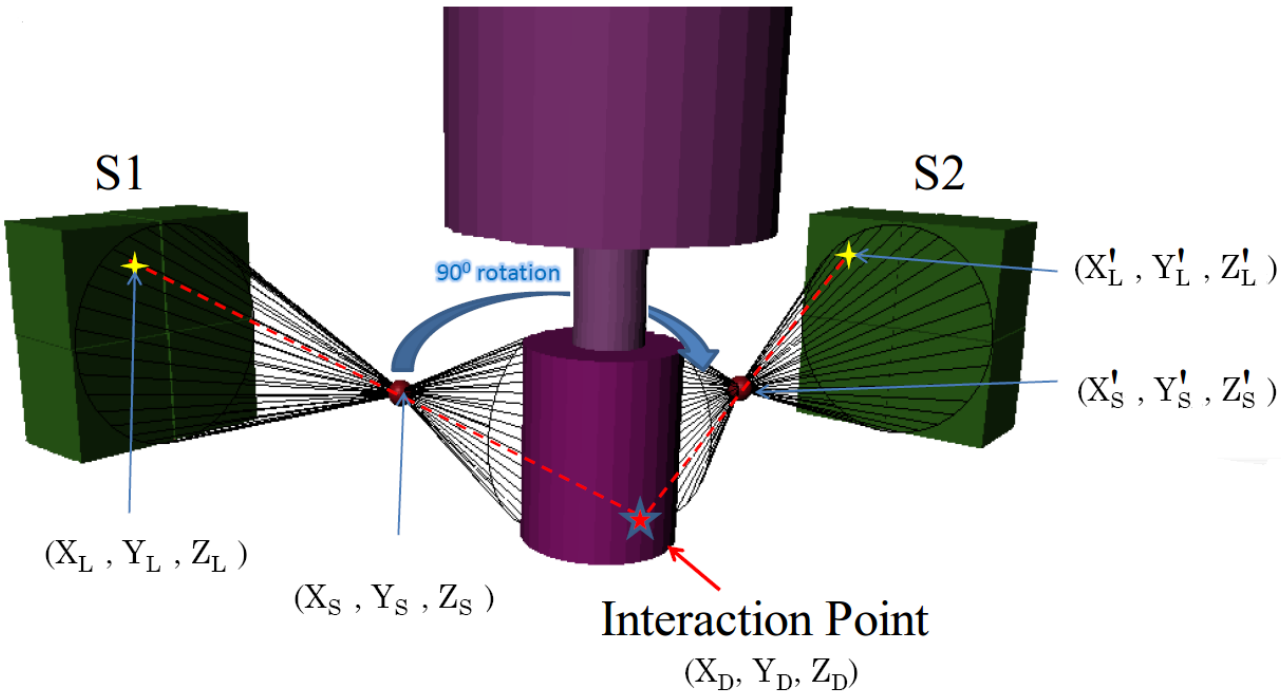
PSD detector

- 4 LYSO crystals
- 4 PMT pixelated
- Active area: 100x100 mm
- 8 Flash ADC Caen
- Resolution ~ 0.7 mm

Analogical coincidence system

Epipolar geometry

Pulse shape comparison method



χ^2 test as pulse shape comparison

Test description

- χ^2 test is the PSC most used:

$$\chi^2 = \frac{1}{n}\sum_{i=1}^{n}\frac{(x_i - y_i)^2}{y_i}$$

- Problem 1: differences between pulses are very small.
  - The χ^2 value associated to a confidence level is not sensitive to different pulse shapes.
- A figure of merit has to be built in order to select a threshold.

Noise problem

- Problem 2: the response of the test is not uniform with the noise to signal ratio.

Groups		Noise value					
		0.03	0.01	0.003	0.001	0.0003	0.0001
χ^2	0.03	13	12	11	11	11	11
	0.01	42	**25**	**25**	**25**	**25**	**25**
	0.009	49	26	**25**	**25**	**25**	**25**
	0.006	120	28	26	26	**25**	**25**
	0.003	611	37	27	27	26	**25**
	0.001	999	81	27	27	26	**25**
	0.0009	999	106	27	27	26	**25**
	0.0006	1000	300	38	28	27	26

Experiment description:
25 different pulses are used in the test.
A Gaussian noise is added to each signal 40 times to complete one thousand pulses.
The χ^2 test is used for different noise and critical value.

Wilcoxon pulse shape comparison

New pulse shape comparison

- Based in Wilcoxon non-parametric test.
  - Used in the comparison of two paired samples when the population cannot be assumed normally distributed.
  - It is a signed-rank test so the value of the differences and its sign is important.
  - Critical value of the test:

$$R(z) = \frac{n(n+1)}{4} - z\sqrt{\frac{n(n+1)(n+2)}{24}}$$

- Adaptation: Wilcoxon test is sensitive to the noise fluctuations so differences below a threshold (MinT) are cero value.

- Let be two samples $X=\{x_i\}$ and $Y=\{y_i\}$ of size n. Thus, there are a total of 2n data points.
- Calculate the differences of the samples: $D=\{d_i\}$

$$d_1=x_1-y_1,\ d_2=x_2-y_2,\ \dots\ ,\ d_n=x_n-y_n$$

- Order the differences from smallest absolute difference to largest absolute difference.
- Rank the pairs R_i, starting with the smallest as 1. Ties receive a rank equal to the average of the ranks they span.
- Calculate the test statistic, the absolute value of the sum of the signed ranks.

$$\text{If } sig(d_i)>0 \quad R_+ = \Sigma\{R_i\}\ ; \qquad \text{If } sig(d_i)>0 \quad R_- = \Sigma\{R_i\}$$

- The samples are non-statistically different if:

$$\{R+,\ R-\} > R\{z\}$$

Noise problem solved

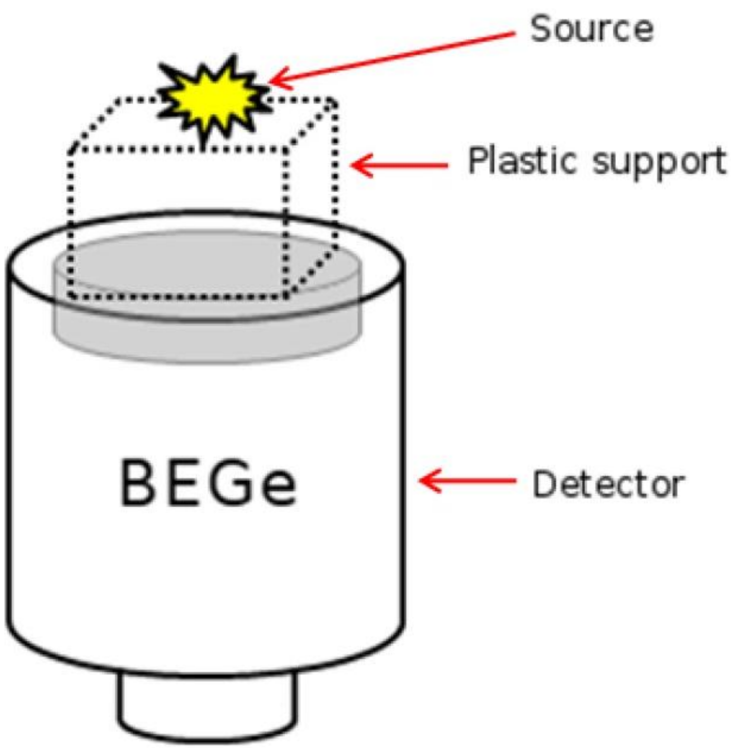
- The problem of the noise presented in χ^2 is solved with the Wilcoxon test.

Experiment description:
25 different pulses are used in the test.
A Gaussian noise is added to each signal 40 times to complete one thousand pulses.
The χ^2 test is used for different noise and critical value.

	Groups	Noise value					
		0.03	0.01	0.003	0.001	0.0003	0.0001
MinT	0.09	17	14	14	12	12	12
	0.06	26	21	22	19	18	18
	0.03	58	28	**25**	**25**	**25**	**25**
	0.01	158	78	35	**25**	**25**	**25**
	0.009	157	91	39	**25**	**25**	**25**
	0.006	183	130	49	26	**25**	**25**
	0.003	211	184	68	35	**25**	**25**
	0.001	229	223	107	49	32	**25**
	0.0009	218	214	112	53	34	28

Results

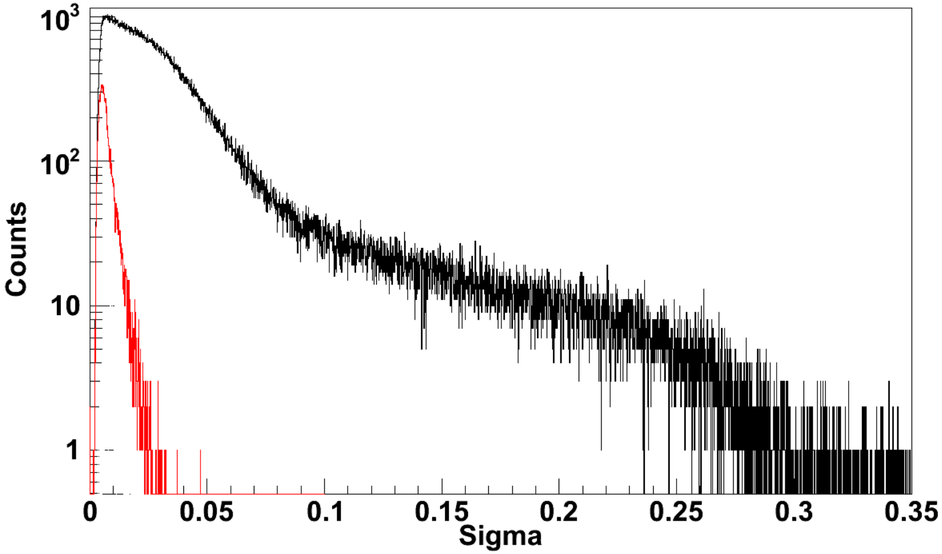
BEGe characterization



The detector employed in this work to test the method is a Broad Energy Germanium detector (BEGe), Canberra model BE5030.

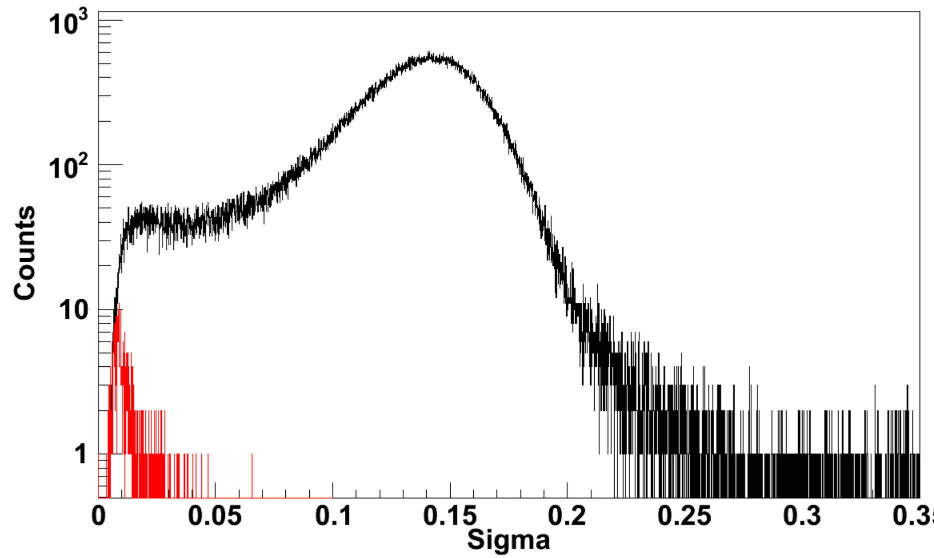
A 244 kBq ^{137}Cs not-collimated source was measured in the position depicted in the figure, which correspond to a distance equal to 143 mm from the detector center

	Noise	Groups	σ
Experimental	3.49×10^{-3}	118	3.22×10^{-2}
Simulation	3×10^{-3}	104	3.72×10^{-2}



The black line shown the histogram with the sigma comparing one pulse with all the pulses for the analysis.
The red line with only the sigma for the pulses grouped with the Wilcoxon PSC algorithm.

These type of histograms are the used in χ^2 test for the figure of merit(FOM).
The pulses selected in the PSC test are only the pulses with a low value of σ, according the χ^2 comparison techniques based in the FOM.



Conclusions

- The PSC method with the Wilcoxon test do not need a arbitrary value as the used in the figure of merit.
- Also the precision of Wilcoxon test is uniform with different signal to noise ratios in contrast with response not uniform of the χ^2 test.
- The new PSC method is very useful to make a characterization of a HPGe detector with the new scanning method because it is a fast but powerful test.
- The pulses could be grouped as the first part of the HPGe characterization and reduce the large amount of data in the experiment.

References:

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Thanks for your attention