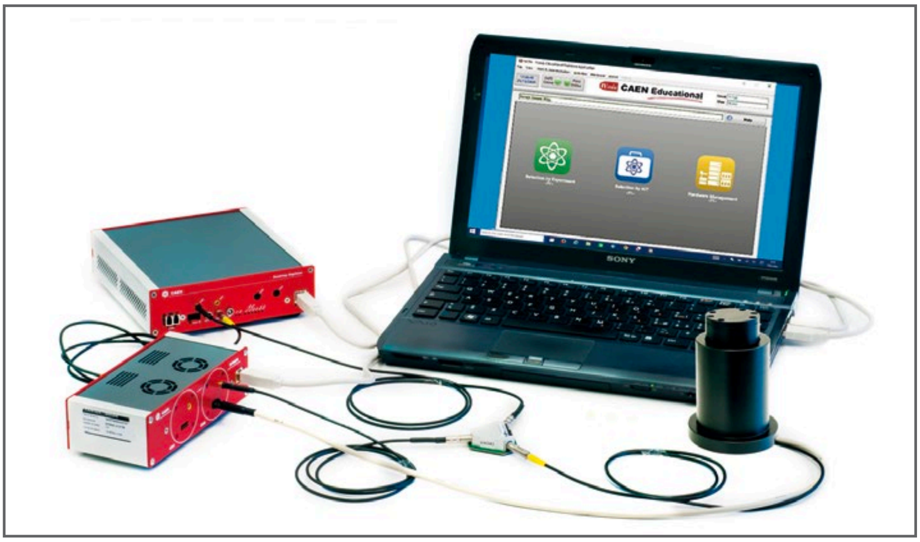
B.1.5 SG6115 A Comparison of Different Scintillating Crystals: Light Yield, Decay Time and Resolution



Ordering Options

Equipment A	
Code	**Description**
WK5600XCAAAA	SP5600C - Educational Gamma Kit
or the all inclusive Premium Version	
WK5600XANAAA	SP5600AN - Educational Kit - Premium Version

Equipment B	
Code	**Description**
WK5630ENAAAA	SP5630EN - Environmental Kit
or the Kit Plus	
WK5630XENAAA	SP5630ENP - Environmental Kit Plus

Purpose of the experiment

Compare the basic characteristics of different scintillating crystals, namely the light yield and the decay time of the scintillation light. Verify the effect on the energy resolution.

Fundamentals

Scintillating materials have different characteristics related to the light yield and the characteristics time of the emission. The CAEN spectrometer is provided with three different crystals: BGO (Bismuth Germanate), LYSO(Ce) (Cerium-doped Lutetium Yttrium Orthosilicate), CsI(Tl) (Thallium-doped Cesium Iodide). All of them have the same volume (6 x 6 x 15 mm^3), are polished on all sides and coated with a white epoxy on 5 faces. One 6 x 6 mm^2 face is open in order to be coupled with the Silicon Photomultiplier. The main characteristics of the crystals are summarized in the following table:

	BGO	LYSO(Ce)	CsI(Tl)
Density (g/cm³)	7.13	7.4	4.51
Decay Time (ns)	300	40	1000
Light Yield (ph./MeV)	8200	27000	52000
Peak emission (nm)	480	420	560
Radiation length (cm)	1.13	1.14	1.85
Reflective index	2.15	1.82	1.78

The light yield is having an impact on the energy resolution. This is also affected by the decay time, constraining the integration time and implying a different effect of the sensor stochastic effects (dark counts and afterpulses).

The scintillation is by physics definition the process by which ionization produced by charged particles excites a material causing light to be emitted during the de-excitation. When you excite a material and it subsequently gives off light, that is luminescence: fluorescence is photoluminescence or scintillation (i.e. excitation produced by ionizing radiation) that has a fast decay time (ns to μs) and phosphorescence is the same, only with a much slower decay time (ms to seconds). Among the scintillator characteristics:

- light yield: high efficiency for converting ionization energy to light output [photons/MeV]
- decay time: how long it takes the excited states to de-excite and give off light(can be different for alphas and betas because depends on ionization density)
- density and Z: determine response to γ, e^- and other electromagnetic processes.

Scintillator crystals are widely used in detectors for gamma-rays, X-rays, cosmic rays and particles whose energy is of the order of 1 keV and also greater than this value. A scintillator crystal is a crystal which is transparent in the scintillation wavelength range, which responds to incident radiation by emitting a light pulse. Such detectors are used especially in industry for thickness or weight measurements and in the fields of nuclear medicine, physics, chemistry and oil exploration

http://www.physics.queensu.ca/~phys352/lect19.pdf

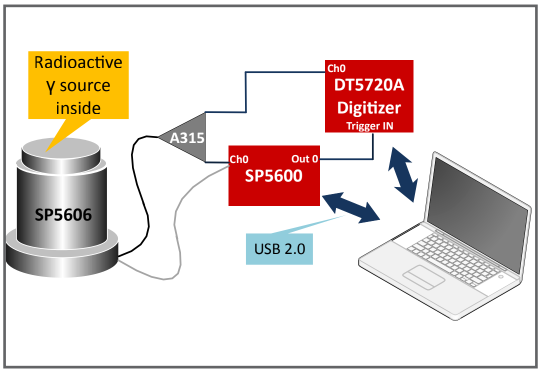
Equipment

SP5600C - Educational Gamma Kit

Model	SP5600	SP5606	A315	DT5720A	SP5607
Description	Power Supply and Amplification Unit  p. 145	Mini-Spectrometer  p. 147	Splitter  p. 147	Desktop Digitizer 250 MS/s  p. 145	Absorption tool  p. 148

Requirements

Gamma Radioactive Source



Experimental setup block diagram.

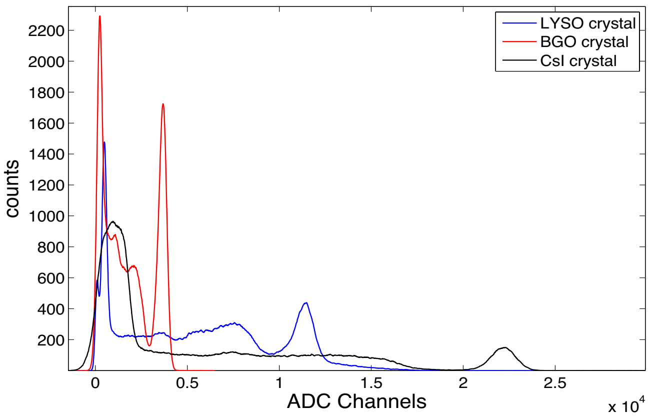
Carrying out the experiment

The scintillator crystal shall be coupled to the SiPM in the SP5607, through a thin layer of index matching grease to maximize the light collection. In order to avoid saturation, the output of the SiPM is divided using the A315 splitter: one branch is connected to the DT5720A and will be digitized. The other branch will be amplified by the SP5600 module, generating the trigger for the integration signal by the on-board leading edge discriminator. The discriminator threshold shall be defined looking at the spectrum and evaluating the dark count rate. Once this is set and the radioactive source is properly positioned, the spectrum can be recorded. The procedure shall be repeated for every crystal.

Results

The crystal characteristics are investigated recording a source spectrum (for example ^{137}Cs) with the three different crystals, optimizing the integration time as a function of the scintillation decay time.

According to table, the Light Yield of the three crystal is very different. LYSO(Ce) has a light yield three times greater than the BGO, and CsI(Tl) light yield is twice than LYSO(Ce). The analysis of the signal waveform or the trend of the charge vs integration time leads to the measurement of the time characteristics of the scintillator.



^{137}Cs energy spectra. Blue spectrum corresponds to the acquisition through LYSO crystal, the red and black ones respectively with BGO and CsI crystals.

	Light Yield Ratio (from datasheet)	Peak Position Ratio
LYSO/CsI	0.52	~0.51
LYSO/BGO	3.29	~3.11
BGO/CsI	0.16	~0.16

Experimental results of Light Yield Ratio