

**COMPACT PULSE PROCESSOR**  
**for high resolution spectroscopy with**  
**Cadmium Telluride detectors**

**CHARGE LOSS CORRECTOR**  
**MODEL CPP II-NIM**

**OPERATION MANUAL**



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## TABLE OF CONTENTS

<b>DESCRIPTION</b> .....	<b>3</b>
<b>SPECIFICATIONS</b> .....	<b>5</b>
1. PERFORMANCE .....	5
2. CONTROLS.....	5
3. INPUT.....	5
4. OUTPUTS.....	5
5. ELECTRICAL AND MECHANICAL.....	6
<b>INSTALLATION</b> .....	<b>6</b>
1. CONNECTION TO POWER.....	6
2. CONNECTION TO PREAMPLIFIER .....	6
3. LINEAR OUTPUT CONNECTION.....	6
<b>THEORY OF OPERATION</b> .....	<b>7</b>
<b>HOW TO USE YOUR CPP II</b> .....	<b>9</b>
1. INSTALLATION.....	9
2. TEST WITH A RADIATION SOURCE .....	10
<b>HOW TO OBTAIN BETTER PERFORMANCES</b> .....	<b>17</b>

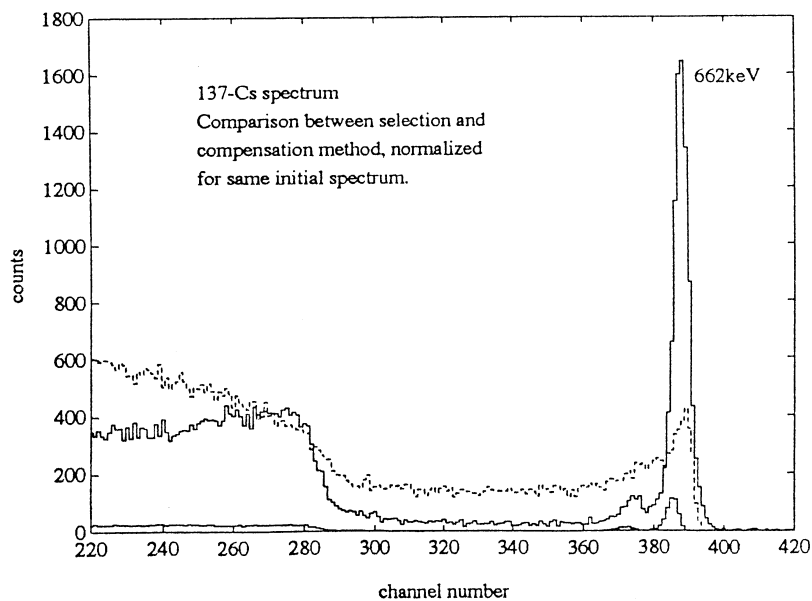
## DESCRIPTION

The EURORAD Charge Loss Corrector Model CPP is intended for spectrometric applications of planar CdTe and HgI<sub>2</sub> detectors. To improve energy resolution and photopeak efficiency in this device the functions of a normal spectroscopy amplifier are combined with a special designed electronic pulse processing unit. The Model CPP can operate with pure pulse shape discrimination or in a combined mode of pulse preselection and the newly developed charge loss compensation. Timevariant pulse shaping ensures short amplifier deadtime and increases the system throughput at high counting rates.

There are two main factors which degrade the energy resolution of planar CdTe and HgI<sub>2</sub> detectors. The first one, the ballistic deficit is caused by large variations of charge collection time. It is overcome with an adapted timevariant pulse shaping method.

**Figure 1:**

The combination of <sup>137</sup>Cs spectra measured with selection (filled) and correction (solid line) normalised for same initial spectrum (dotted line) illustrates the gain of photopeak efficiency using the correction method.



The second one, trapping and recombination in the bulk of the detector, is compensated using a method published by Richter and Siffert.<sup>1</sup>

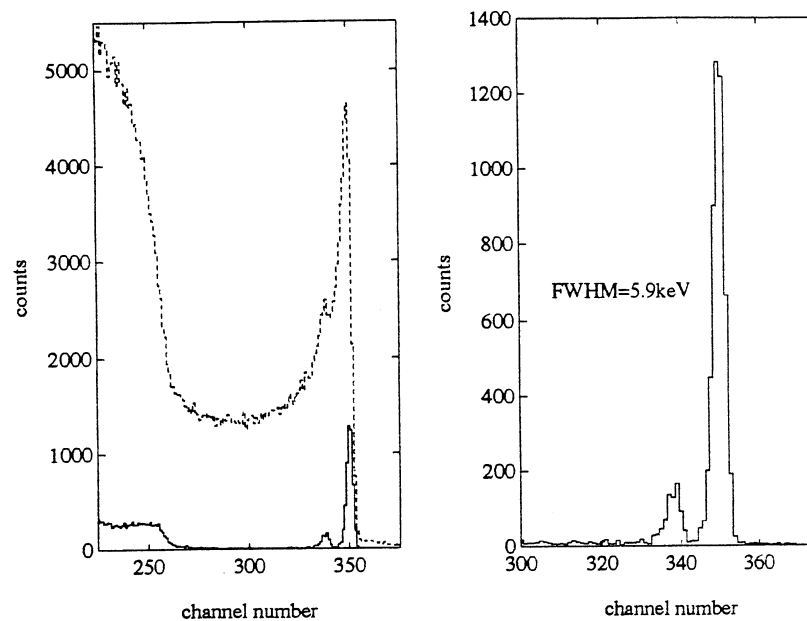
<sup>1</sup> Richter M., Siffert P., High resolution spectrometry with CdTe detector systems, 7th Internat. Workshop on Room Temperature X- and Gamma- Ray Detectors, September 23-28, 1991, Ravello - Italy.

Resolution and full energy peak efficiency of compound semiconductor gamma radiation detectors have been limited up to now by charge losses due to recombination of a more or less significant fraction of the photogenerated carriers. The resulting loss in pulse amplitude gives rise to low energy tailing of the photopeak. To enhance energy resolution pulse shape discrimination methods selected only signals that had been generated under optimum conditions. But the price for the improvement of energy resolution was an appreciable loss of detection efficiency.

A correlation between the fractional energy loss and the charge collection time has recently been discovered. Furthermore, this relationship is largely independent of the photon energy and is a constant property of the detector.

### **Figures 2 + 3:**

Peak at an energy of 662 keV of a  $^{137}\text{Cs}$  spectrum measured with pure pulse selection. The resolution is about 6 keV. This spectrum is the same as the filled one of Figure 1.



This discovery is used in the CPP. It corrects each pulse coming from a planar CdTe or HgI<sub>2</sub> spectrometer by an amount exactly equivalent to the charge lost by recombination. Thus pulses in the low energy tail are transferred into the photopeak. This results in better energy resolution, peak-Compton and peak-valley ratios in a gain of photopeak efficiency.

The performance of the Model CPP is illustrated in Figure 1. A spectrum measured with a small risetime selection window with disabled compensation (filled) is compared with another recorded using the preselection-compensation mode of the Model CPP with a much larger risetime window (solidline). The spectra were measured with the same measuring geometry and are normalised for the integral counts over the entire spectrum (dotted line). The gain of height of the photopeak is about ten.

If you deal with high radiation source activities or the measuring time doesn't play any role, you can profit from the slightly better energy resolution of the pure selection mode. Figures 2 + 3 show the filled spectrum of Figure 1 in another scale.

## SPECIFICATIONS

### 1. PERFORMANCE

- GAIN RANGE: Continuously adjustable from X25 through X1500.
- PULSE SHAPING: Gated Integrator.
- INTEGRAL NONLINEARITY: Less than 0.2% (typically 0.1%).
- MAXIMUM INPUT COUNTING RATE: 100.000 cps (137-Cs source).
- DYNAMIC RANGE: 20 - 1500 keV.

### 2. CONTROLS

#### FRONT PANEL

- INPUT POLARITY: Toggle switch +/-.
- GATE: Enables output gate.
- COMP.: Enables compensation.
- FINE GAIN: Precision potentiometer for a continuously variable gain factor of X0.5 to X1.5.
- COARSE GAIN: Five-position selector switch selects gain factors of 50, 100, 200, 500 and 1000.
- THRESHOLD: Screwdriver potentiometer to adjust the lower threshold level of the pulse detector.
- THRESHOLD LED: Control the noise level of the system "preamplifier + detector".
- SELECTION: Precision potentiometer to select the maximum risetime.
- COMPENSATION: Precision potentiometer to calibrate the compensation to obtain optimum resolution and peak symmetry.

### 3. INPUT

- IN: Type BNC front panel connector. DC-coupled. Accepts signals of a charge sensitive preamplifier, both polarities, rise times in a range from 150 ns to 2500 ns, decay time constants from 0.05 ms to 1 ms; input impedance about 1 KOhm; linear ac maximum 0.5 V; absolute maximum 10 V.

### 4. OUTPUTS

- OUTPUT ENERGY: Unipolar output of the energy signal. Gated/ungated, type BNC front panel connector,  $Z_o = 50 \text{ Ohm}$ , short circuit proof, full scale range 0 to + 3 V.
- PREAMP POWER: Front panel 9-pin Amphenol connector, ORTEC standard, provides  $\pm 12\text{V}$  and  $\pm 24\text{V}$ .

## 5. ELECTRICAL AND MECHANICAL

- POWER: (not including any load on the Preamp Power Connector) . The Model CPP derives its power from a standard NIM bin and power supply. Power required is +12V at 75mA and -12V at 55mA.
- WEIGHT: 1.2 Kg
- DIMENSIONS: standard double-width NIM module.

## INSTALLATION

### 1. CONNECTION TO POWER

The CPP contains no internal power supply and must obtain the necessary dc operation power from the bin and power supply in which it is installed for operation. Always turn off power for the power supply before inserting or removing the module. After installing all modules in the bin and connecting of any preamplifier, the dc voltage levels should be checked to see that they are not overloaded.

### 2. CONNECTION TO PREAMPLIFIER

The preamplifier output signal is connected to the CPP through the INPUT BNC connector on the front panel. The input impedance is about 1 KOhm and is dc coupled to ground. Therefore, the preamplifier output must be either ac coupled or have approximately zero dc voltage. The internal pole zero cancellation is optimised for a preamplifier decay time constant of 0.05 ms but it will work in a wide range. Preamplifier power at  $\pm 12$  V and  $\pm 24$  V is available through Preamp Power connector on the front panel. The detector-preamplifier combination should have a sensitivity of not less than 250 mV/MeV. Check the position of the input POLARITY switch (up: negative).

### 3. LINEAR OUTPUT CONNECTION

The OUTPUT of the CPP should be connected to the linear input of the ADC or MCA. The maximum output voltage is 3 V.

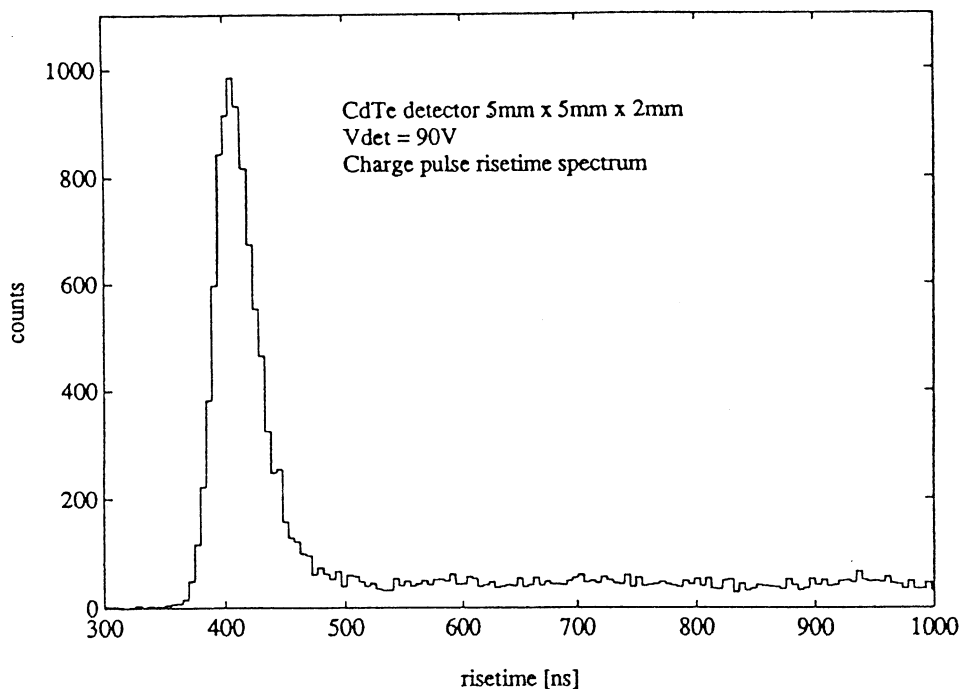
## THEORY OF OPERATION

The planar detector shape is currently the most commonly produced and applied CdTe detector type. Because of the nearly uniform electrical field inside, both electrons and holes take part in the charge collection. Since the mobility product of the electrons is about ten times bigger than that of holes, the collection time depends largely on the depth of the charge generation. Both charge carriers have nearly the same lifetime. Thus, the charge collection losses are mostly associated with losses of the hole component.

Normally a semiconductor detector is irradiated through the negative electrode. At the surface the absorption of a photon is most probable. The charge is mainly collected by electrons. This shortest collection time is determined by the electron transit time. The maximum in the risetime distribution (Fig. 4) near minimum risetimes corresponds to the interactions near the entry.

**Figure 4:**

Risetime distribution of the preamplifier pulses.



Because of the omit electron collection the recombination losses are small. Events near the surface with short collection times are registered in the full energy peak.

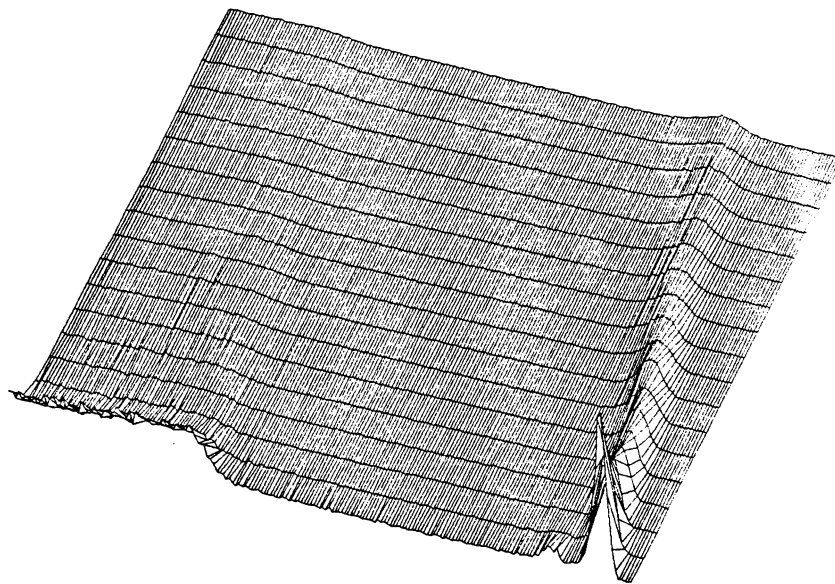
In the case of deeper interactions the hole fraction of the collection current is more important. Due to the lower hole mobility the overall collection time is longer and therefore the fractional recombination and trapping losses higher. In the spectrum the event is stored in the

low energy "tail" of the photopeak.

The channel-position of an event in a spectrum depends not only on the initial photon energy and the type of interaction but also on the depth of the charge generation. Since the electric field inside of the planar detector is nearly uniform, a function of fractional charge loss versus collection time exists. In experiments this function was measured. It is illustrated in Figure 5. This two-dimensional spectrum of a  $^{137}\text{Cs}$  source was registered using the ungated ENERGY and TIME outputs of the CPP.

**Figure 5:**

This two-dimensional  $^{137}\text{Cs}$  spectrum shows clearly the linear replacement of the 662 keV photopeak versus longer charge collection times.



For correction we assume electron collection without any losses. Only hole trapping can be compensated. In case of bad detectors where not only the holes but also the electrons are captured, the compensation fails.

Based on the linear fractional loss versus risetime a compensating circuit has been designed. It multiplies a value proportional to the charge collection time  $t_{\text{coll}}$  with the height  $E$  of the degraded pulse. The result is amplified with a variable gain  $K$  (potentiometer COMPENSATION) and added to the voltage of the initial pulse. The corrected output voltage  $E_{\text{corr}}$  can be calculated as following:

$$E_{\text{corr}} = E + K * (t_{\text{coll}} * E)$$

It has been found, that this linear relationship is valid in a wide range of risetime and is independent of gamma radiation energy.

## HOW TO USE YOUR CPP II

### 1. INSTALLATION

For the first use of your CPP you should begin by testing the device with a pulse generator.

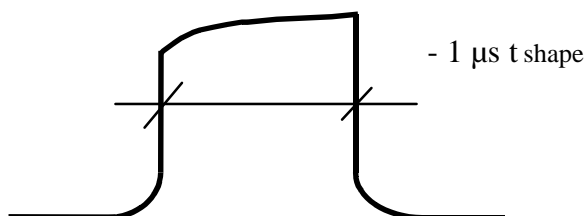
You should proceed as follow:

- 1) Insert your CPP in your RACK NIM. Always turn off power for the power supply before inserting or removing the module.
- 2) Connect the INPUT of your CPP to a pulse generator test. The pulse risetime should not exceed 50 ns. The decay time constant ranges from 0.05 ms up to 0.5 ms. Adjust the pulse voltage at approximately 0.1 V.
- 3) Set the polarity switch on the front panel to the desired position:
  - upper switch position: positive pulses;
  - lower switch position: negative pulses.

Set the functions as follow:

- COARSE GAIN: 50
- FINE GAIN: 5.0
- THRESHOLD: Turn the screwdriver potentiometer full counterclockwise.
- COMPENSATOR: 0
- SELECTOR: 10.0
- GATE: Disable (lower switch position).
- COMP: Disable (lower switch position).

- 4) Connect the output of the CPP to an oscilloscope.
- 5) Turn the threshold clockwise in order to obtain a stable signal.
- 6) You should see on the oscilloscope a 1  $\mu$ s square wave signal.



- 7) Adjust the FINE GAIN in order to obtain an amplitude of 2 volts.

8) In order to test the COMPENSATOR functions proceed as follow:

- COMP: Enable (upper switch position).
- GATE: Disable (lower switch position).
- COMPENSATOR: Full counterclockwise to position 0.

Turn the 10 turn COMPENSATOR potentiometer (from 0 to 10) and observe the amplitude of the signal which should increase.

9) The internal risetime SELECTOR can be tested as follow:

- GATE: Enable (upper switch position).
- COMP: Disable (lower switch position).
- SELECTOR: full clockwise to position 10.0

Turn the SELECTOR potentiometer counterclockwise. At position 0 no output signal should be measured.

**In situation where the CPP is suspected of a dysfunction, please return it to EURORAD's facility.**

## 2. TEST WITH A RADIATION SOURCE

You can now test your CPP with a detector and a radiation source.

As a first step, you should check if your detector can be used with the CPP.

### HOW TO CHECK THE COMPATIBILITY BETWEEN YOUR DETECTOR AND THE CPP

**Introduction :** The device performs a linear compensation of trapping losses by calculating a correction term from the collection time of a charge pulse and its height. This function can be described as follow:

$$V_{out} = V_{in} (1 + K \cdot t_r)$$

where

$V_{out}$  = corrected pulse height

$V_{in}$  = initial pulse height

K = correction factor.

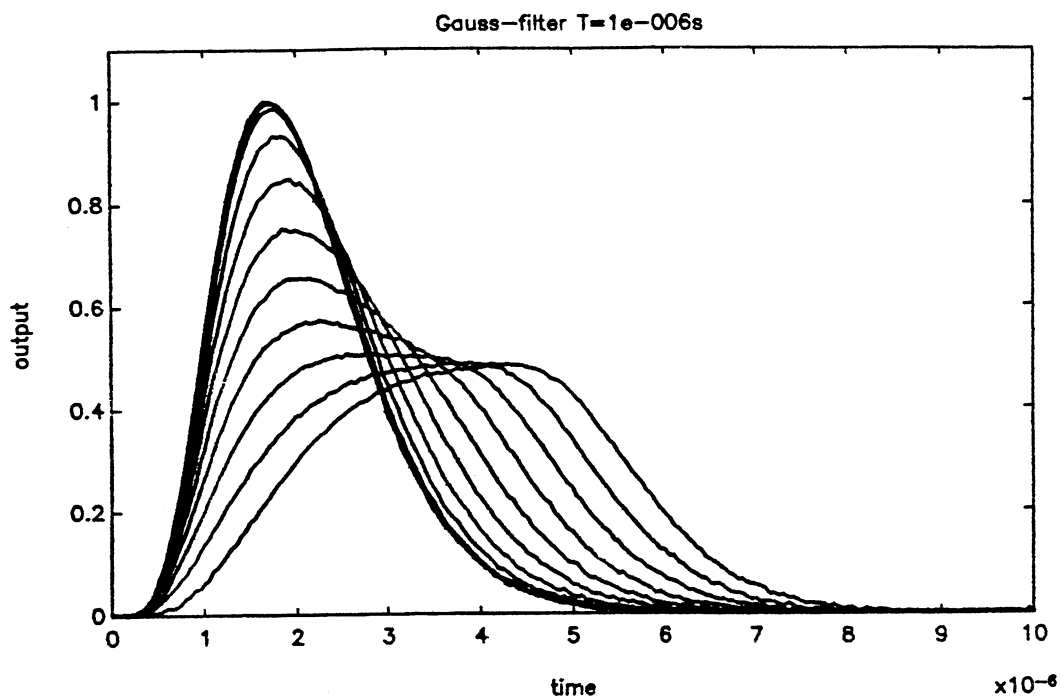
The correction factor K depends on the applied bias voltage and is a detector property. Normally, in the CPP II model, you can adjust the Compensation with a 10 turn potentiometer (in the CPP I model you had to add a resistance in order to adapt the detector).

**Detector's test :** This test is performed by using a gaussian amplifier.

1. Connect the detector to the preamplifier.
2. Connect the preamplifier to a normal gaussian amplifier (ORTEC 571 or similar).
3. Apply to your planar CdTe detector the nominal bias voltage. The shaping time should be  $1\mu\text{s}$ .
4. Use a gamma ray energy above 100 keV.
5. Connect your gaussian amplifier to an oscilloscope and observe a certain number of "long pulses". This is encouraging.

**Figure 7:**

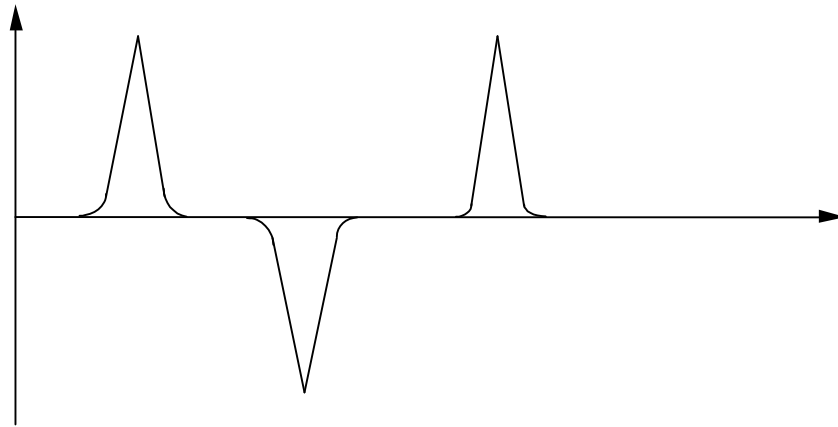
"Long" pulses at the output of a gaussian amplifier.



## OPERATION MODE

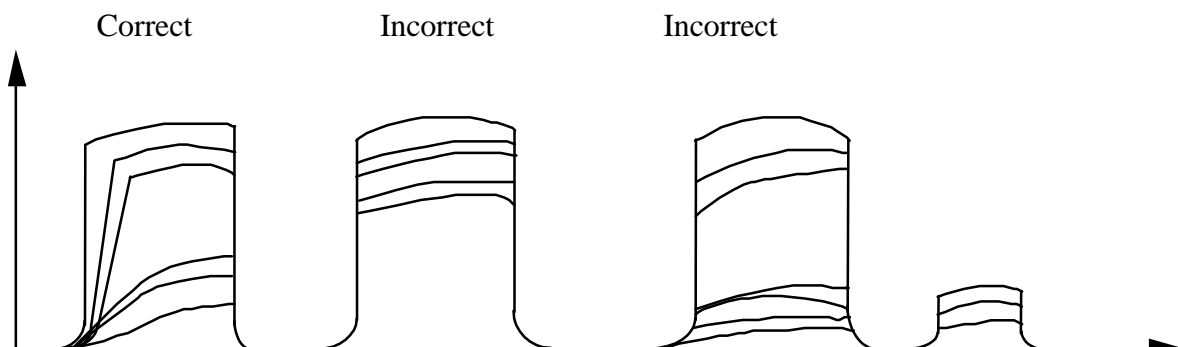
### Installation and pole zero

1. Connect the detector to the preamplifier.
2. Connect the Amphenol DB9 preamplifier to the CPP.
3. To check the pole zero of your preamplifier connect a square wave generator to the test input of the preamplifier and connect the output of the preamplifier to an oscilloscope. The signal should return to the base line.



**Threshold adjustment :**

1. Connect the preamplifier output to the CPP input.
2. Apply the nominal bias voltage to the detector and wait a few seconds until the high voltage on the detector gets stabilised.
3. Connect the CPP output to an oscilloscope and MCA.
4. The CPP's functions should be set as follow before use:
  - Threshold screwdriver: Full counterclockwise.
  - Threshold Led: OFF
  - COMPENSATOR: Full counterclockwise, position 0.
  - SELECTOR: Full clockwise, position 10.
  - GATE: Disable (lower switch position).
  - COMP: Disable (lower switch position).
  - COARSE: 50
  - FINE: 5.0
  - POLARITY: Will depend on the preamplifier output pulses:
    - upper switch position = negative polarity
    - lower switch position = positive polarity.
5. Adjust the threshold screwdriver in order to obtain intermittent flashes of the red Led.
6. Place a 137-Cs source on the top of the detector. The red Led will be continually bright (ON).
7. Adjust the output signal to 2 volts with COARSE and FINE GAIN.
8. Adjust the threshold as low as possible.



**Operation in compensation mode :**

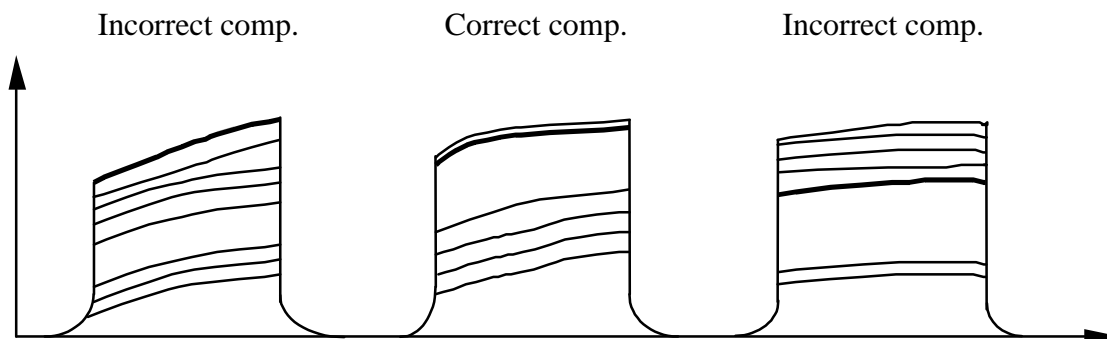
Set the functions as follow:

- GATE: Disable
- SELECTOR: Position 10.0
- COMP: Enable (upper switch position).
- COMPENSATOR: Full counterclockwise, position 0.

In the compensation mode a correction circuit transfers pulses from the low energy "tail" into the photopeak. This operation enhances the energy resolution and photopeak efficiency. It enables high resolution spectrometry with CdTe and HgI<sub>2</sub> detectors and shortens the measuring time.

In order to optimize the photopeak shape you should use the compensation mode without SELECTOR (GATE disable).

Turn the COMPENSATOR potentiometer clockwise and observe the signal on the oscilloscope.



On your MCA you can get different spectra (see Figures 8,9,10 and 11).

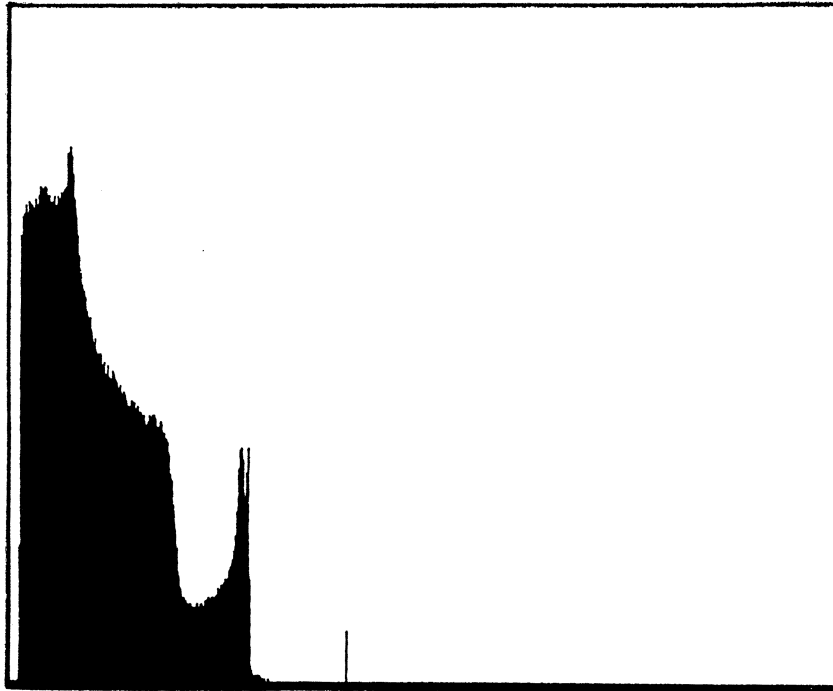
**Figure 8:**

Initial 137-Cs spectrum: COMP: Disable, GATE: Disable



**Figure 9:**

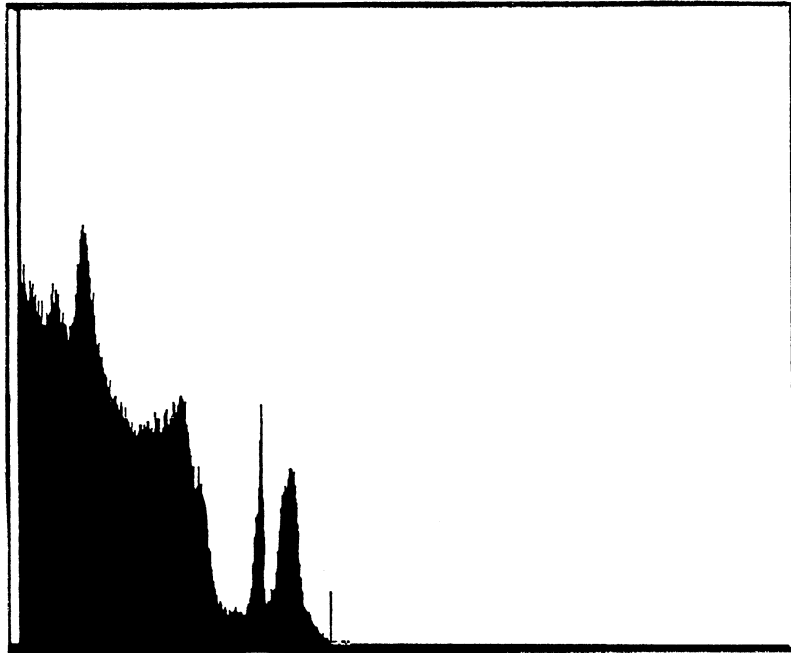
Undercompensated  $^{137}\text{Cs}$  spectrum, increase COMPENSATION



**Figure 10:**

$^{137}\text{Cs}$  spectrum with optimum compensation adjustment



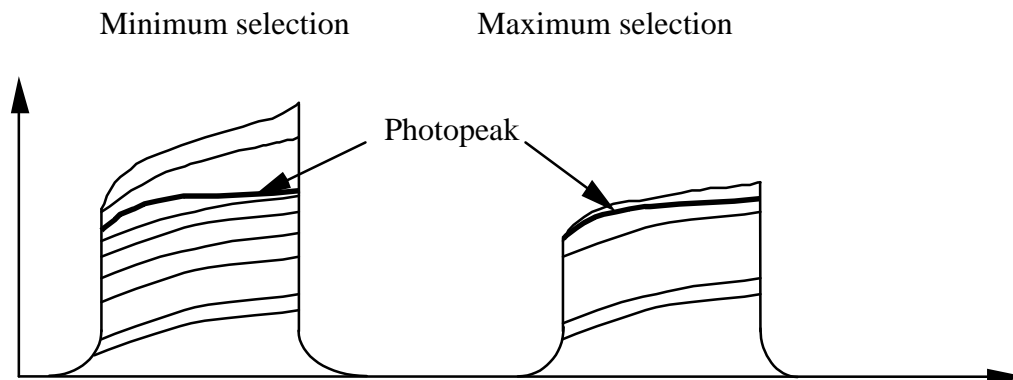
**Figure 11:**Overcompensated  $^{137}\text{Cs}$  spectrum decrease COMPENSATION**Operation in selection mode :**

In this operation mode you can obtain better energy resolution but the appreciable loss of detection efficiency limits its application. It should be used in case of high radiation source activities or if there are no restrictions for measuring time.

In order to select the risetime proceed as follow:

- COMP: Enable (upper switch position).
- COMPENSATOR: Position where you get the optimum  $^{137}\text{Cs}$  spectrum.
- GATE: Enable (upper switch position).
- SELECTOR: Full clockwise, position 10.

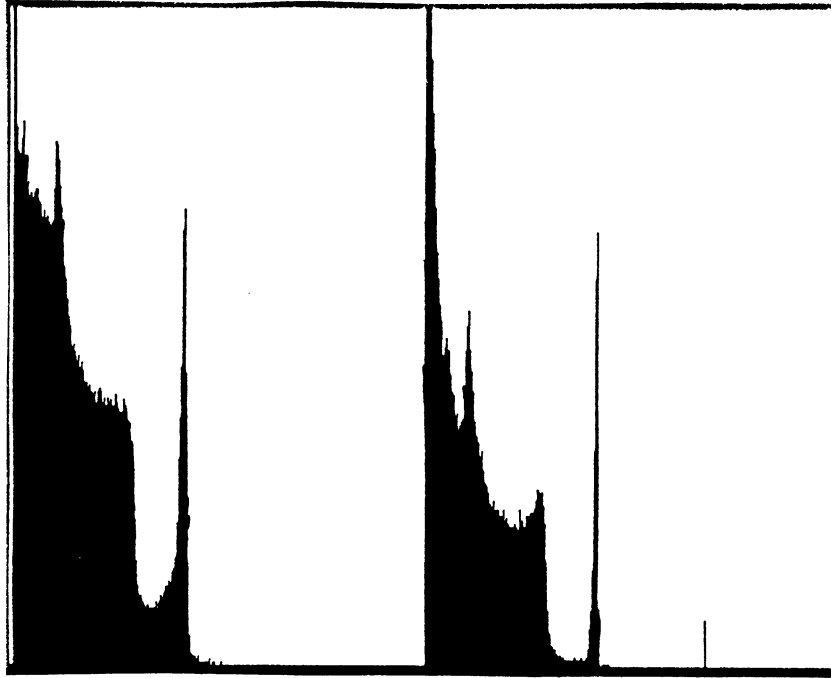
To exclude pulses with long risetimes and therefore to enhance the energy resolution turn the SELECTOR potentiometer counterclockwise and observe the signal obtained on the oscilloscope.



The spectrum of the Figure 12 shows the maximum and the minimum selection you can have.

**Figure 12:**

Comparison of two  $^{137}\text{Cs}$  spectra  
Left: SELECTOR = 10, Right: SELECTOR = 3.1



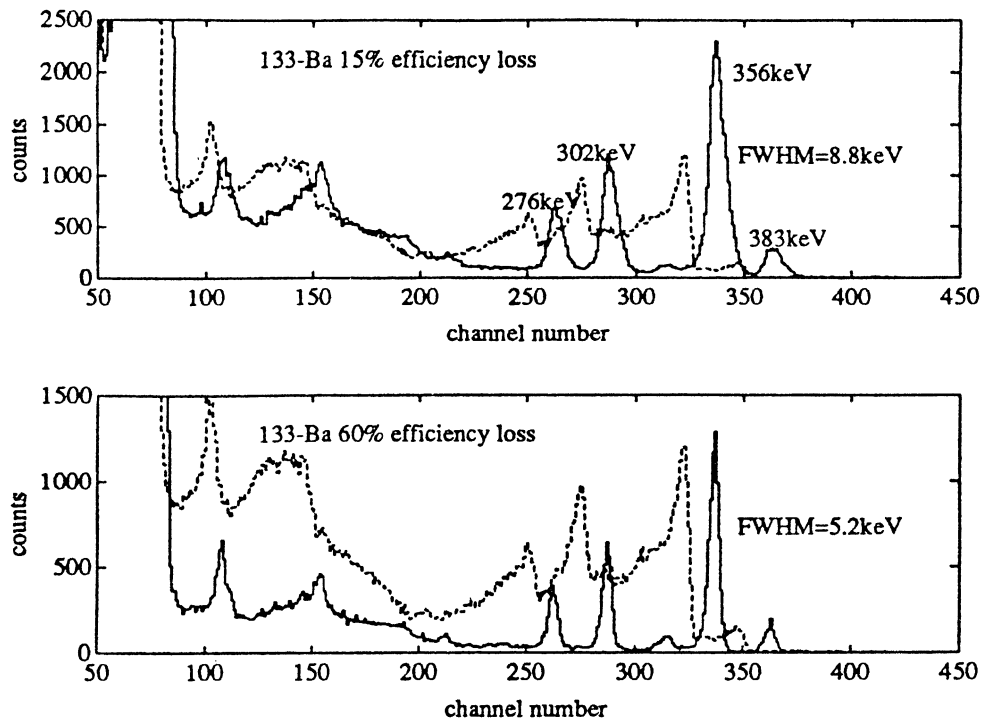
**Resolution / efficiency optimisation :**

The pulse preselection influences basically the efficiency and the energy resolution. The smaller the risetime window the better the resolution but the higher the efficiency loss.

As an example, the Figure 13 illustrates this relation between the efficiency and the energy resolution.

**Figure 13:**

$^{133}\text{Ba}$  spectra measured with CPP and different preselection (solid line) in comparison with the initial spectrum (dotted line).



## HOW TO OBTAIN BETTER PERFORMANCES

You must be aware that all CdTe detectors are not compatible with the CPP since they have to present a certain number of characteristics as developed in section 6.2.

All EURORAD detectors are tested with the CPP and we can therefore assure you that they can be used with the CPP.

**However, in case of troubles, questions or suggestions do not hesitate to contact us.**